INDUSTRIAL RESEARCH

NOVEMBER 1961

now monthly!

can you afford government R & D contracts?

THE TECHNICAL MAGAZINE FOR MANAGEMENT

NOVEMBER 1961 **RE**

THE COVER *depicts the deadly game of chess being played over our planetary checkerboard by the "reds" and the "whites"—a new game these days because the weapons are rockets instead of queens, taking their places beside conventional kings and pawns. Outcome of the game is questionable because the rockets have unrestricted movement (they fly), and it's hard to see how smart chess players could have gotten themselves into such a situation.*

The photograph introduces a series of articles beginning in this issue on the role of the government in research. "Can You Afford Government R&D Contracts?" is the first article, suggesting that companies take a hard look at their expensive fishing expeditions for government contracts. Such contracts are not directly profitable, competition is tough, and cancellation chances are high.

Yet, the rewards can be great, and if your firm seeks government work, be sure to read "How to Get Government Contracts" next issue.

This business of research—one of the few industries grounded entirely in tomorrow—often turns up some really far-reaching considerations. One such is described herein by famous scientist and novelist Arthur C. Clarke, who asks whether the next step in human evolution won't be a mechanical one. "The Evolutionary Cycle from Man to Machine" carries the theme further than we've ever seen it carried before, into a synthesis of man and machine.

GOVERNMENT RESEARCH

Another kind of synthesis, the putting together of organic chemicals to make food, is described by the National Bureau of Standards' Dr. Archibald T. McPherson. McPherson claims "if it grows, we can make it," and if the world population continues exploding at the present rate, we had better.

A new dimension in manufacturing research is explained in the article "Planning Tomorrow's Production Lines." And another of our frequent articles on organizing research, Gen. Leslie E. Simon's "Spectrum Theory," views all applied science from research to production as a continuous spectrum that can be administered by a single management.

Incidentally this is the second issue of Industrial Research to be published monthly.

55,000 copies of this issue printed.
Circulation audited and verified.

Industrial Research is dedicated to reducing the time lag between invention and production. It seeks to do this by informing technical management of new scientific developments and their profitable applications in all fields of industry.

INDUSTRIAL RESEARCH

BEVERLY SHORES, INDIANA

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INDUSTRIAL
NOVEMBER 1961 RESEARCH
THE TECHNICAL MAGAZINE FOR MANAGEMENT

(see page 68)

15

the 15th issue of I·R

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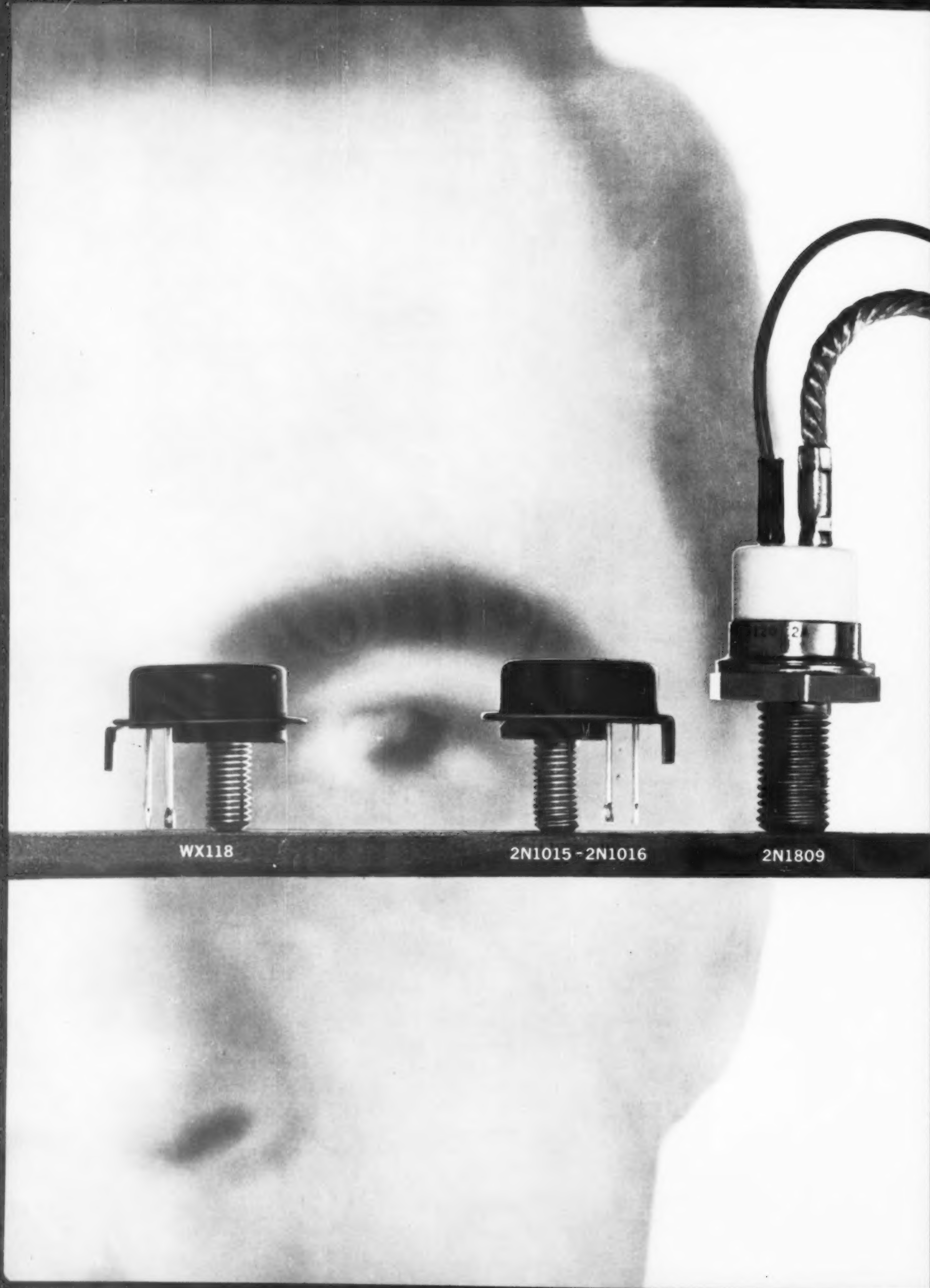
ARTICLES

DEPARTMENTS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FEEDBACK *from technical management*

Fuel cells

Sir:

Drs. De Zubay and Shultz are to be congratulated on an excellent job of summarizing the activities that presently are being carried out in the fuel cell field (Vol. 3, No. 4). This is one of the best summaries of the subject that I have seen for some time. I might quarrel with some of the conclusions by the authors but this is a matter of personal opinion. For example, I do not feel that the use of a fuel cell power package to generate electricity from gas in individual homes is a practical concept. However, I do not wish to belabor this point.

Everitt Gorin
Manager, Process Research
Consolidation Coal Co.

Sir:

The authors of your article on "Fuel Cells" have done a capable job of summarizing the current state-of-the-art in a very active research area. It may be our ignorance of the particular item, but we felt the sections on the "Direct Use of Coal" on page 24 are not too clear.

H. E. Morris
Technical Director
Monsanto Research Corp.

Sir:

I am enclosing some comments that were prepared by members of our staff after they had read the article on "Fuel Cells:"

1. Why not mention some more civilian applications of the regenerative fuel cell? In the near future when the regenerative hydrogen-oxygen cell is perfected, it could be used for telephone service, emergency lighting, cordless appliances, railroad signal service and car lighting, mine lamps, and aircraft starting.

2. The statement that the thermally regenerative cell "constitutes a heat engine, and is limited by the Carnot efficiency" is true but should be qualified. According to J. B. Friauf (in Thermodynamics of Thermally Regenerated Fuel Cells, J. App. Physics, Vol. 32, No. 4, 616-620, April 1961), the Carnot efficiency can only be attained if the value of a thermodynamic property of the fuel cell reaction is equal to zero. If this value is not equal to zero, the efficiency will be less than Carnot efficiency.

3. Another reason for the use of fuel cells in space, rather than conventional batteries, is the better resistance of some fuel cells to high temperatures in the range of 200 to 300 F.

4. For the sake of completeness, the author might have mentioned the EOS thermally regenerative fuel cell which employs sulfuric acid and makes use of an acid concentration difference between two electrodes. It is regenerated by evaporating water from the concentrated side and condensing it on the dilute side.

5. I believe the Sundstrand Corp. has dropped their development of the nitrosyl chloride cell.

6. The "Redox" principle is not fully explained as he has presented only one-half of the principle. The other half consists of the reaction between air (O_2) and another redox couple such as bromine/bromide or ferrous/ferric.

A. M. Zarem
President
Electro-Optical Systems, Inc.

Isotopic power

Sir:

Dr. Crompton's article on "Isotopic Power" (Vol. 3, No. 4) is exceptionally well written. It should appeal to both laymen and people experienced in the field. It is refreshing to see an article written by an expert in a particular field that would be clear and understandable to the non-expert.

I heartily recommend the article to all personnel involved in power supply problems as an excellent source of information on this new and extremely promising development. I believe that imaginative engineering can develop many uses for isotopic power supplies that will utilize their economic properties. Furthermore such developments would go a long way towards utilization of the waste products generated in the nuclear power field.

C. M. Doede
President
Quantum Inc.

Sir:

Dr. Crompton has done an excellent job in reviewing the development and potential of this unique energy source.

S. L. Fawcett
Manager, Physics Dept.
Battelle Memorial Institute

Sir:

"Isotopic Power" is a very well presented discussion of a most interesting and opportune subject, written by an expert.

Joseph H. Haynes
Isotopes, Inc.

Thermionics

Sir:

The article on "Thermionics" (Vol. 3, No. 4) presents a substantially accurate picture of the status of this field. It is quite true that the success of this field depends heavily on the development of materials that have appropriate characteristics at the unusually high temperatures required of these devices. Some of the effort at General Motors Research Labs. is devoted to this aspect of the problem.

One class of devices not mentioned in the article are those that utilize

"... says he's from the Engineering Society."

noble gas plasmas. Our laboratory has been investigating the use of such gases in an application involving nuclear radiation generated plasmas. This type of plasma also can be generated by auxiliary electrical means which we have demonstrated. This just illustrates that in a new field, such as thermionic conversion, there is a wide variety of new research problems that develop from an initial concept.

As today we see a variety of transistor devices that grew out of the research on the initial concept, tomorrow should see a variety of thermionic converter devices developed from the research now being carried on.

L. R. Hafstad
Vice-President
General Motors Research Labs.

Sir:

The article on "Thermionics" is a well written general interest paper. It should have included the Russian work (N. D. Morgulis and D. M. Marchuck, Ukrainian Phys. J., 2, 359, 1957), which predates the American work on cesium converters. The magnetic triode is now generally considered inoperable and is thus given too much emphasis.

Karl G. Hernqvist
David Sarnoff Research Center
RCA Laboratories

Sir:

The Industrial Research summary article on thermionic converters authored by John Welsh and the late Joseph Kaye is by far the best we have seen for the technical level you wish to reach. Your headline indicates that application depends on a breakthrough in materials technology. At Boeing, the emphasis on research is on single crystal refractory metals as emitters. Reduced sublimation rates and higher power densities are anticipated.

D. W. Exner
Power Generation & Distribution Sec.
Physics Technology Dept.
The Boeing Co.

Solar machines

Sir:

The article on "Solar Machines in Space" (Vol. 3, No. 4) is very well done and technically sound. One point which might have been further emphasized is that, up to the present, the solar cell array has been the only practical energy conversion system for space flights. I think your readers will find this article informative, particularly those not actively engaged in this field of research.

Carl L. Meyer
Supervisor, Advanced Development
and Materials Research
Delco Radio Div.
General Motors Corp.

Sir:

The solar article is very well written and quite accurate. It is unfortunate that the author has used the word 'Somor' to designate the concentrating device, because this also is the name of the Italian solar-powered water pump,

which is used to some extent throughout the Mediterranean countries. It may be that Mr. Oman was not aware of this, or that there is some other reason for using the name, but it certainly creates confusion in the minds of those who are familiar with solar energy technology.

On page 64, the statement is made that Mouchot of France ran the first solar heat engines in 1870. Actually, John Ericsson undoubtedly preceded him by a number of years, perhaps as many as 12, because he was running solar engines of both the steam and the hot air types in the early 1860s. Ericsson should receive credit also for the thousands of engines which were mentioned on page 68, since they were built from his designs.

The figure \$350,000 is used for the cost of enough silicon solar cells to produce one kilowatt of electric power in bright sunshine. My Japanese friends will sell all of the cells we could possibly want for \$100 a watt, rather than the \$350 per watt figure used here, but, even so, the author's point is perfectly correct.

John I. Yellott
President
John Yellott Engineering Associates Inc.

Magnetohydrodynamics

Sir:

Dr. Sodha has given a reasonable elementary discussion of the MHD generator (Vol. 3, No. 4).

I find myself surprised by his statement on page 57, "Breakthroughs were announced almost simultaneously by the Space Sciences Laboratory of General Electric Co., Philadelphia; Avco-Everett Research Laboratory, Everett, Mass.; and Westinghouse Research Laboratories, Pittsburgh. Current efforts undoubtedly were spurred by the advent of the space age." The fact of the matter is that the present great interest in this work was entirely stimulated by our efforts.

Arthur Kantrowitz
Vice-President
Avco Corp.

Sir:

I do not feel that the statement on page 60 in the "Magnetohydrodynamics" article, regarding the current trend of research toward hardware, is entirely accurate. I can from personal knowledge say, for example, that the program of the Advanced Research Projects Agency certainly does not fall into this category. Also, I do not believe that the author has mentioned the possibility of non-equilibrium situations in which one can obtain considerable higher conductivity at most reasonable gas temperatures.

John Huth
The RAND Corp.

Thermoelectricity

Sir:

The "Thermoelectricity" article (Vol. 3, No. 4) is most interesting for executives and management men in

fields not close to the thermoelectricity product line. It is a good understanding of the practical side of thermoelectric devices.

Amasa Pratt
Manager, Techniques Dept.
The Martin Co.

English channel tunnel

Sir:

Your comprehensive story of the English Channel tunnel (Vol. 3, No. 3) was, of course, of great interest to the writer; however, since it was so comprehensive, I was sad that my early planning efforts thereon, a bridge —had never come to your attention.

Incidentally, in reading your article I learned for the first time than another of my earliest plans—a Sub-Aqueas Floating Bridge — for the Golden Gate crossing, had been in some aspects envisioned in 1869 for the Channel crossing. The Russian technical magazines were greatly interested in my plan. One of them had five pages of drawings and data on it as of 1935, and their chief bridge and railroad engineer visited and corresponded with me.

Your readers should be interested in my new breakthrough in metropolitan transportation, the Zero System, which doesn't need a tunnel (or subway) but can be used either as a smaller, cheaper subway or as a new form of "painless" elevated.

Cleve Shaffer
President
Shaffer Engineering Co.

General feedback

Sir:

The publication of significant and authoritative articles that set a field of research in true perspective is a worthy enterprise for a journal like Industrial Research.

James L. Lawson
Manager, Electron Physics Research
General Electric Co.

Sir:

We would like to take this opportunity to congratulate you on the excellent job you are doing in keeping us all informed with the latest up-to-minute developments of the space age.

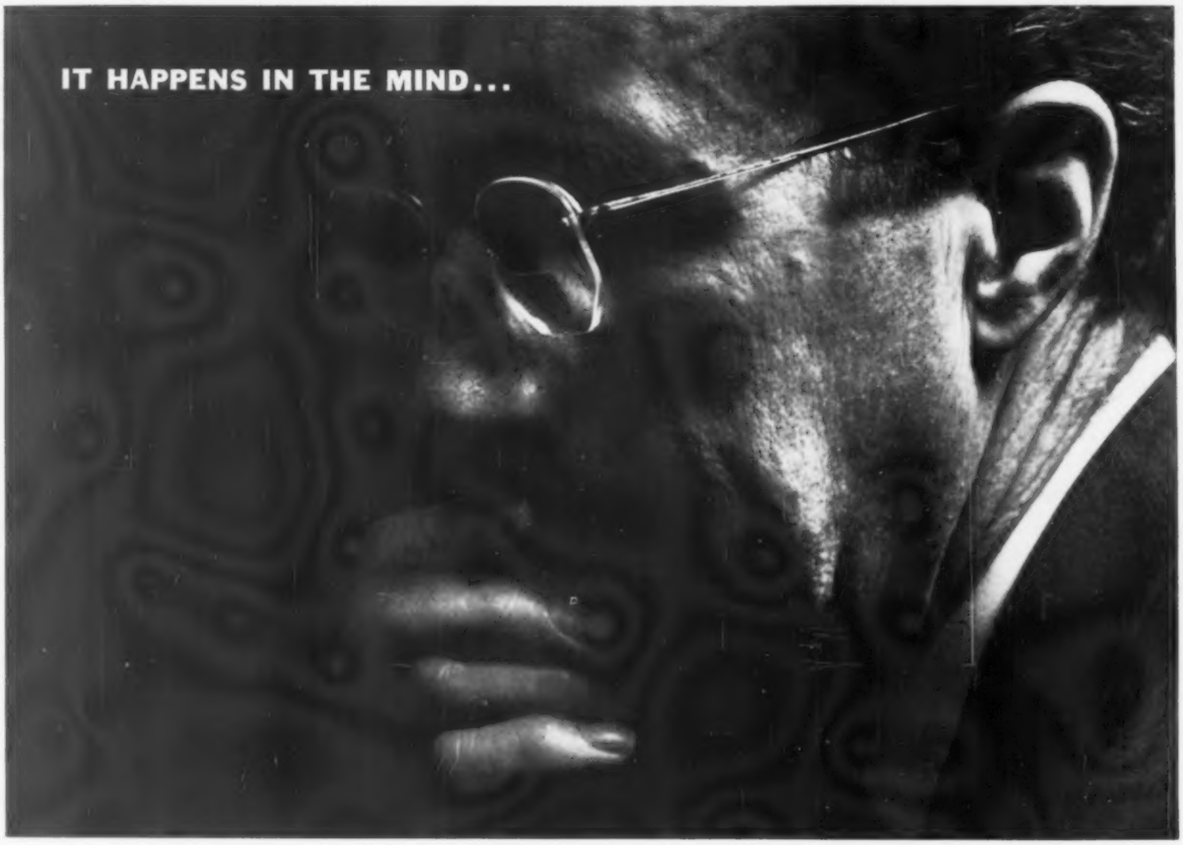
John P. Armstrong
Chief Engineer
Ordnance Research
& Development Co.

Sir:

The Attorney General found the June-July issue enlightening and was pleased to note that Industrial Research will be monthly beginning with the October issue. The article on "Living in Space" alone indicates that the Attorney General will receive many useful ideas from your magazine. There is no question that an understanding of new developments in science is of extreme importance to men in Mr. Kennedy's position.

Edwin Guthman
Special Assistant
for Public Information
Department of Justice

At Bell Telephone Laboratories, mathematician Sidney Darlington has contributed notably in developing the art of circuit analysis.



. . . It is essentially a thing of the mind for it works through concepts, symbols and relationships . . . it helps man to analyze and synthesize the complex phenomena of the universe and himself . . . it works in many ways to advance electrical communications:

IT IS CALLED MATHEMATICS

At Bell Telephone Laboratories mathematics works powerfully to solve problems involving complex data. For example, engineers must design and synthesize complex systems to process specific signals in precisely controlled ways. At the same time the technology provides a wide choice of circuits and components. Mathematical circuit analysis reveals the circuits which can do the job most efficiently and economically.

Intriguingly, too, the mathematical approach leads to basically new knowledge. For example, it led to the invention of the electric wave filter . . . disclosed a kind of wave transmission which may some day carry huge amounts of information in waveguide systems . . . foretold the feasibility of modern quality control . . . led to a scientific technique for determining how many circuits must be provided for good service without having costly equipment lie idle.

In the continuing creation of new devices, technologies and systems, Bell Laboratories utilizes whatever serves best—mathematical analysis, laboratory experimentation, simulation with electronic computers. Together they assure the economical advancement of all Bell System communications services.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

by **Melvin Mandell,** *I·R contributing editor*

can you afford government R & D contracts?

At least 60% of the money spent in this country each year on research and development comes out of the U.S. treasury. Significantly, this amount covers proportionally more of the most advanced fields.

As an illustration of the technically top-heavy demands of government contracts, a recent survey showed that 75% of the nation's active electronics engineers work on equipment for the government although this hardware represents only 60% of the electronics industry's dollar volume.

Much of this R&D work has potential commercial applications. Most company officials, of course, are well aware that many of today's important industries and products are outgrowths of government-funded research. Just consider the great examples from World War II: atomic energy, jet engines, radar, the mass-production of antibiotics, the jeep,

the aerosol insecticide bomb, and dozens of lesser-known products.

Offshoots of government R&D spending

Although we are not in a shooting war, the swords-into-plowshares evolution has not abated. Reading machines, hydrofoil ships, and infrared instruments are three prime examples of potentially important lines of commercial products that are recent offshoots of current government R&D spending:

■ *Machines that read* and record numbers and letters up to a hundred times faster than a human will cut the cost of putting great masses of information into high-speed computers.

At least four of the companies that are building or plan to build commercial reading machines have gained knowhow in this field by performing R&D for various branches of the government. Baird-Atomic Inc., 33 University Rd., Cambridge, Mass., built a machine for the Air Force (for $600,000) that reads Russian technical journals into an IBM translating computer. Control Instrument Co., a subsidiary of Burroughs Corp., built an experimental machine for the Signal Corps under a $385,000 R&D contract that reads typewritten messages into communication circuits at the rate of 750 words a minute. Philco Corp. currently is working on a research contract from the U.S. Post Office to develop a reading machine that can sort letters with typewritten addresses by states. A Philco executive admitted that the company won't make any money on the contract, but the company didn't go after the job to make a profit.

Even the leader in this field, Farrington Manufacturing Co., Needham Heights, Mass., was bolstered by building a new type of machine for the Air Force. The Intelligent Machines Research Corp., now a Farrington subsidiary, already had built and installed seven commercial machines that read only numbers, when it received a $327,000 contract from the Air Force Research & Development Command for a machine that would read letters and punctuation marks as well.

IMC delivered the "Print Reader MX2021" to the Air Force in June, 1959, two years after it received the contract. A year and a half later, the company introduced its commercial "page reader," which it frankly admits to be an outgrowth of the experimental Air Force machine.

A billion-dollar business in 5 years

Reading machines as computer input devices are only one example of how the government is stimulating the technology of high-speed data-processing. Besides these machines, which could generate "a billion-dollar business in five years" (according to Jacob Rabinow, president of Rabinow Engineering Co., Washington, D.C.), the Department of Defense is pushing development of other "peripheral" computer equipment and of the central unit, the computer itself.

■ *Most management men feel that to stay in the research swim their companies must go fishing for government R&D contracts. However, there is another side to the question: government contracts are not directly profitable, competition is tough, and cancellation chances are extremely high. This article is the first in a series describing the government's role in our nation's $14-billion expenditure for industrial research . . . In the next issue, I•R will feature . . . "How to Get Government R&D Contracts" and "Will the Department of Commerce Really Back Basic Research?"*

This powerful stimulus has resulted in a strange situation in which the computer industry is technologically five years ahead of its commercial customers. While the situation may not be comfortable, it's a lot better than being five years *behind* the needs of the market.

▪ *Hydrofoil ships* provide another example of swords-into-plowshares research. Much of the American hydrofoil technology that eventually will create fleets of these fast, low-flying ships was generated under government sponsorship. Because they take the sea-sickness out of rough-water passage, they will find widespread commercial use as ferries to off-shore islands and for commuting into our great port cities.

For a decade the Navy has sponsored theoretical studies and the construction of experimental hydrofoil-equipped ships. The most important R&D project from a commercial point of view, however, is the *H. S. Denison*. A 104-ft hydrofoil boat, the *Denison* was built in a hangar by Grumman Aircraft Engineering Corp., Bethpage, N.Y., and hauled through the streets of Long Island towns to the Sound (see photo on page 17). Now the experimental $5-million craft is being outfitted at a boatyard on Long Island Sound preparatory to sea trials early next year.

The *Denison* was constructed under a $1.5-million R&D contract from the Maritime Administration. Grumman and the many component and material suppliers are making up the other $3.5-million. General Electric Co. is accepting only $1 for adapting an aircraft jet engine as the main propulsion unit.

Of course, Grumman and the supplier companies cooperating on the project hope to make up their investment through commercial orders. Already Grumman has received a contract from a Florida ship operator for hydrofoil ferries similar to the *Denison* to operate between Florida and the Bahamas. One obstacle: the contract is automatically cancelled if the *Denison* doesn't perform as expected.

Low bids may be an investment

Another company investing a lot of its own money in an experimental hydrofoil, over and above R&D funds from the government, is The Boeing Co. The big aircraft and missile manufacturer is building the 110-ton *PCH* for the Navy for $2,080,000. Boeing has not revealed how much of its own money is being sunk into the hydrofoil craft, but the sum must be considerable if the smaller *Denison* will cost $5-million. A Bureau of Ships official told INDUSTRIAL RESEARCH that he was "very surprised at the lowness" of Boeing's bid.

Besides the two vessels described above, the Navy is inviting bids on a 300-ton sub destroyer. While the hulls and foils are the major components to be developed for these revolutionary ships, other key elements, such as power plants and electronic control systems, will be needed. For instance, the Bureau of Ships has entered into a "joint agreement" with the Pratt & Whitney Aircraft Div. of United Aircraft Corp., East Hartford, Conn., to modify the J-75 jet engine into a power plant for hydrofoil ships. The designation "joint agreement" implies that the Navy isn't going to pay Pratt & Whitney very much, if anything, for the research and engineering involved.

▪ *Infrared instruments* provide a third example of military projects with industrial application. The military is spending hundreds of millions of dollars for "passive" detection systems that intercept the heat or infrared rays given off by everything. The Army wants to detect foot soldiers on moonless nights; the Air Force hopes to spot intercontinental missiles.

Two companies that successfully have converted technology gained in government work into commercial infrared products are Servo Corp. of America, 111 New South Rd., Hicksville, N.Y., and Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. Servo has developed the hot box detector for railroads. Mounted beside the tracks (see photo on page 17), the device detects dangerously overheated journal bearings on the axles of railroad freight cars. (All passenger cars are equipped with

This article is adapted and expanded from Melvin Mandell's forthcoming book, Stretching Your Research Dollar, *which will be published next year by McGraw-Hill Book Co. Inc.*
A contributing editor to Industrial Research, Mandell is director of technical evaluation at Globus Inc., a New York underwriting and financial house. Previously, he was industrial editor of Dun's Review & Modern Industry, and, before that, editor of Research & Engineering and associate editor of Electronic Design. He has contributed to many magazines, including The International Executive, Popular Electronics, and Petroleum Today, and has written a chapter in Miniaturization, a technical book published by Reinhold. Mandell is a graduate of the School of Engineering and of the Graduate Faculties of Columbia University.

roller bearings rarely subject to catastrophic failure.) Dozens of railroads have purchased one or more of the $20,000 systems. The motivation to buy is simple: hot boxes cause wrecks costing millions of dollars a year.

Barnes Engineering developed an infrared camera for the Army that also has many civilian applications. Since the exposure time of this unusual camera is very slow compared to cameras that detect visible light, it can "photograph" only motionless objects, such as men, vehicles, and tanks standing still.

Peacetime applications are varied. Because the camera responds to minute differences in temperature, a Canadian surgeon believes that the camera can detect cancers and infections lying close to the skin. Such malignancies are slightly warmer than normal tissue.

The infrared camera also has many industrial applications (see photo on page 18). For example, by photographing the outside of an open hearth furnace, it can tell where the refractory bricking is wearing thin on the *inside*.

Simple inventions wanted

These three examples refer to sophisticated machines. It is important to remember that the government isn't interested only in big, complex, expensive systems. While the lion's share of federal research funds is aimed at such exotic hardware as satellites, spaceships, and nuclear-powered vehicles, there remains a huge hunger on the part of the military and other government agencies for simpler equipment and new materials. Here's a sampling from the latest *Inventions Wanted by the Armed Forces and Other Government Agencies* that should have immediate and profitable commercial application:

- Methods to prevent snow or ice accumulation on runways, taxiways, and ramps.
- A reliable way to determine incipient failure of the life remaining in dynamic components such as gears and bearings so that premature removal for inspection and tear-down may be avoided.
- A lightweight, reusable, leakproof tube fitting for high-pressure fluids.
- Low-vapor-pressure lubricants and greases capable of resisting prolonged exposure to vacuum conditions.
- Plastics or other types of very thin, inexpensive coatings for mild steel for use in distillation equipment as protection against sea water corrosion. They have to be long-lasting at temperatures up to 300 F. (R&D funds for devices that convert seawater into fresh water could increase sharply in coming years.)
- A sealing method and transparent sealing tape that could be used in solar stills and have long life under outdoor weather conditions.
- A device that can sense the difference between

TRANSPORTATION, *whether by aircraft (left), ship (above), or railroad (below), has had an enormous push toward civilian use by government spending. The model of an advanced aircraft inlet air duct at left is undergoing tests at simulated altitudes of 150,000 feet in a hypervelocity shock tunnel at Republic Aviation Corp., Farmingdale, L.I. The model is seen through a camera observation porthole in a vacuum tank portion of the 120-ft-long tunnel, as air streaks by at Mach 20 (about 15,200 mph).*
The H. S. Denison, *shown above being hauled through the streets of Long Island towns to the Sound, is a 104-ft hydrofoil boat built in a hangar by Grumman Aircraft. The $5-million experimental craft, which has civilian application as a commuters' vehicle for close-to-water cities, is to begin sea trials early next year.*
Another project that has converted government-gained knowledge successfully into commercial product is Servo Corp.'s infrared "hot box detective system," shown below as it scans the trailing surfaces of passing journal boxes to spot the overheated journal bearings (hot boxes). Information obtained by the scanner is stored in a computer; if a hot box is spotted, the information is radioed automatically to the train crew.

snow, rain, hail, and sleet, and feed an appropriate signal into an electronic system.

- A simple, inexpensive device for recording the maximum and minimum values reached by a galvanometer since reset.
- A method for instantaneous measurement of mass flow rate in a liquid propellant transfer line.
- A simple means of determining blood pressure in any part of the body without entering the body. (Such a device, applicable only for cerebral areas, that fits like a pair of goggles over the eyes, has been built by The Decker Corp., Bala Cynwyd, Pa.)
- A bird repellant to keep birds off the tracks during rocket sled runs. It must not interfere with the functions of the sled, track, or any associated equipment, and should not kill the bird. (What a godsend for "gingerbread" encrusted buildings.)

It is obvious that government-sponsored research and development covers practically the entire spectrum of technology today. This situation leads to only one conclusion. In the words of a top expert in the field, Dr. Lawrence Bass, vice-president of Arthur D. Little Inc.: "Some companies feel obliged to take R&D contracts as a defensive move to keep abreast of developments in a classified field of interest to the company."

Of course, no company really is forced to go after R&D contracts, despite strong inducements to do so. It is still possible to examine the pros and cons of doing research for one or more of the government agencies and make a decision on the basis of what is best for the company.

The disadvantages of government contracts

Here are the disadvantages:

- *Profits are low.* The primary incentive for entering into any business should be the opportunity to make a profit. Unfortunately, this is the poorest inducement in the government R&D business. Maximum profits are severely limited by law, while the chances of taking a loss are great. Government auditors are very strict in allowing costs to be charged against contracts. They often disallow what businessmen consider normal costs of operation, such as entertainment and advertising.

What's more, even if the company makes a profit on every contract it receives, it may lose money on its entire government R&D business. Costs of presenting technical proposals to the government and of preparing bids are high and getting higher all the time as projects become more complicated. A low rate of success in bidding could wipe out any profits.

To make matters worse, the chances of bidding successfully on contracts are declining as competition gets tougher every year. Some companies charge that some giant firms, particularly in the aircraft industry, knowingly take R&D contracts at a loss in order to break into a fast-growing technical field.

■ *Cancellation chances are high.* Even if a company is successful in obtaining a contract, there's always the strong possibility of the government cancelling the contract, or simply running out of funds for the project, or failing to appropriate funds to continue the project beyond the original fiscal year. Cancellation clauses usually are generous enough to protect the company from dollar loss, but they do not compensate for wasted time and poor use of scarce technical talent.

Despite the objections, there are sound reasons for companies to go after R&D contracts. Here are the main ones:

■ *Production contracts often follow R&D contracts.* One of the keys to obtaining potentially profitable production contracts is to develop a prototype first under an R&D contract. If the military or other federal agency needs the equipment in a hurry, or if it decides that the company has unique technical capabilities, it will dispense with the time-consuming bidding process and negotiate the contract only with the company that developed the prototype.

Loral Electronics Corp. is one example of a technically oriented company that has been eminently successful in defense work through advanced R&D work. President Leon Alpert claims that the key to his company's success in obtaining production contracts is close liaison with the military. By always being aware of defense needs and perhaps anticipating them, Loral is able to work in advanced fields that are not too competitive and in which it is likely to gain contracts on a negotiated, more profitable basis.

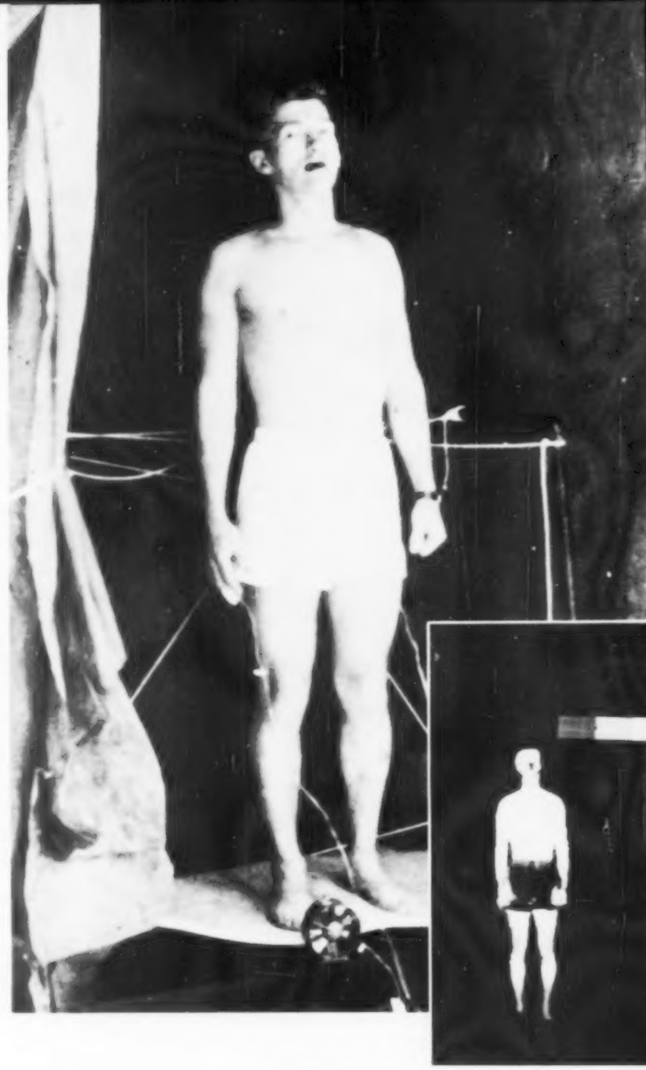
■ *Commercial rights may be retained.* The major fringe benefit to doing research business with the government is the retention of commercial proprietory rights on any patents granted.

Unfortunately, these rights now are threatened. The Atomic Energy Commission and the National Aeronautics & Space Agency traditionally have retained these commercial rights, as prescribed in the acts that brought them into being. Certain Congressmen and defense officials today are active in attempts to modify DOD regulations so that the government retains commercial rights on military contracts as well.

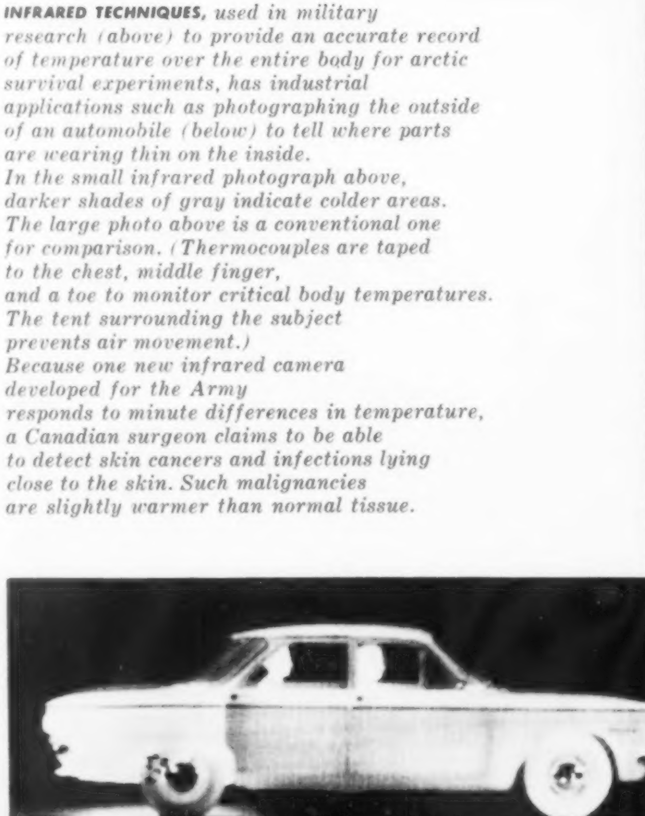
Sen. John McClellan (Democrat, Ark.) has introduced a bill that would give the United States exclusive title to any invention developed under a government contract. Another bill with a similar objective has been introduced by Sen. Russell Long (Democrat, La.). These bills have been backed by many well-known scientists and engineers, mainly connected with universities.

Furor over patent legislation

Needless to say, industry is horrified at the possibility that such bills will be passed. Even though similar bills have been introduced in years past and



INFRARED TECHNIQUES, *used in military research (above) to provide an accurate record of temperature over the entire body for arctic survival experiments, has industrial applications such as photographing the outside of an automobile (below) to tell where parts are wearing thin on the inside. In the small infrared photograph above, darker shades of gray indicate colder areas. The large photo above is a conventional one for comparison. (Thermocouples are taped to the chest, middle finger, and a toe to monitor critical body temperatures. The tent surrounding the subject prevents air movement.) Because one new infrared camera developed for the Army responds to minute differences in temperature, a Canadian surgeon claims to be able to detect skin cancers and infections lying close to the skin. Such malignancies are slightly warmer than normal tissue.*



failed to pass both houses of previous Congresses, industry has been mustering its heavy "articulary" against the legislation. The National Assn. of Manufacturers, the Manufacturing Chemists Assn., and the less-well-known Strategic Industries Assn. have all sent spokesmen before Congressional committees to denounce the bills.

Industry spokesmen claim that the technical progress of the nation would be impeded seriously if industry could not retain commercial rights. They point to the slow progress of atomic energy in the U.S. as proof of their position. Although they don't claim that atomic energy would be competitive with fossil fuels if the AEC hadn't retained commercial rights, they contend that more progress would have been made.

In support of this position, an officer of one defense contractor, Perkin-Elmer Corp., has admitted that his company refuses to take on any AEC or NASA contracts that might have eventual commercial applications.

Industry spokesmen insist that no one would benefit from government retention of commercial rights. They point out that few companies would be willing to license these rights on the indicated non-exclusive basis when they know that many others can do the same.

Industry is counterattacking by giving solid support to other pending bills that would change AEC and NASA patent regulations to conform with the more liberal rules of the Department of Defense.

Despite the furor over various contending bills, it appears likely that none of them—either supported or opposed by industry—will be passed by this Congress. But that won't discourage the enemies of a liberal commercial patent rights arrangement from trying to upset the DOD's present position. Will they have more success in future Congresses?

'We lost money, but it helped us recruit!'

■ *Defense contracts provide an opportunity for recruiting better research workers.* Right after the first U.S. astronaut made his historic flight into space, a vice-president of Motorola Inc. told the author that he didn't know if his company made any money on the parts of the space capsule that it supplied, but that participation in the program was a big aid in recruiting.

Young PhD research men just out of the university nearly always ask if the company participates in any advanced fields, according to this executive. Even if these young men are not specifically promised an opportunity to work in the advanced fields, they favor the companies that do.

Unfortunately, if the company is not heavily ininvolved in space and other exotic programs, it is likely to lose these young professionals to other companies. Hopefully, however, technical graduates will be mature enough to accept whatever responsibilities are assigned to them and not seek an elusive glamour elsewhere.

■ *Government work provides the opportunity to build a more well-rounded, viable laboratory.* One of the lesser fringe benefits of government R&D work is the opportunity to hire researchers in greater number and quality.

Many fields of commercial research do not justify hiring a full-time professional. But if some government research work is obtained in the same special fields, a company may be able to hire researchers on a full-time basis that it could not afford otherwise.

Expensive instruments may be acquired on the same basis. With a government contract in the house, the company can buy or lease a valuable instrument and then rent time on it to its commercial research projects. Similarly, a larger library with more professional library aides or a more complete model shop can be justified.

Scientists are social creatures

The opportunity to increase the size of a laboratory can be important. While large laboratories call for high administrative skills, a very small research lab can suffer from the inability to create a proper intellectual atmosphere. The addition of government research contracts often permits a small company to expand its necessarily small laboratory to a scope that promotes a more stimulating by-play of ideas among professionals. Despite the legend of the lone genius, scientists are very much social creatures.

■ *Government work offers an entree to "invitation-only" technical conferences.* To stimulate technical advances in areas of special interest, the Army, Navy, and Air Force sponsor special technical conferences. Attendance usually is secured by invitation only and limited to the employes of defense contractors working in that area. In many instances the conferences are classified and, therefore, open only to people with security clearances.

The right to participate in these conferences and also to obtain copies of classified research reports may be one of the prime intangible fringe benefits for companies that perform research for the government. To be denied access to these rich sources of information actually could take a company out of contention in some crucial technical area.

Each company must decide, on the basis of these factors, whether to go after government R&D contracts—and how many it can *afford* to take on. Performing research for government agencies offers substantial benefits, balanced by considerable risk and nearly constant aggravation. As long as the U.S. continues to struggle with communist nations, so much of our technological progress will be geared to national needs that few research-oriented companies will be able to avoid performing research for the government—even at an apparent loss. ■

as the world's
more births than deaths per
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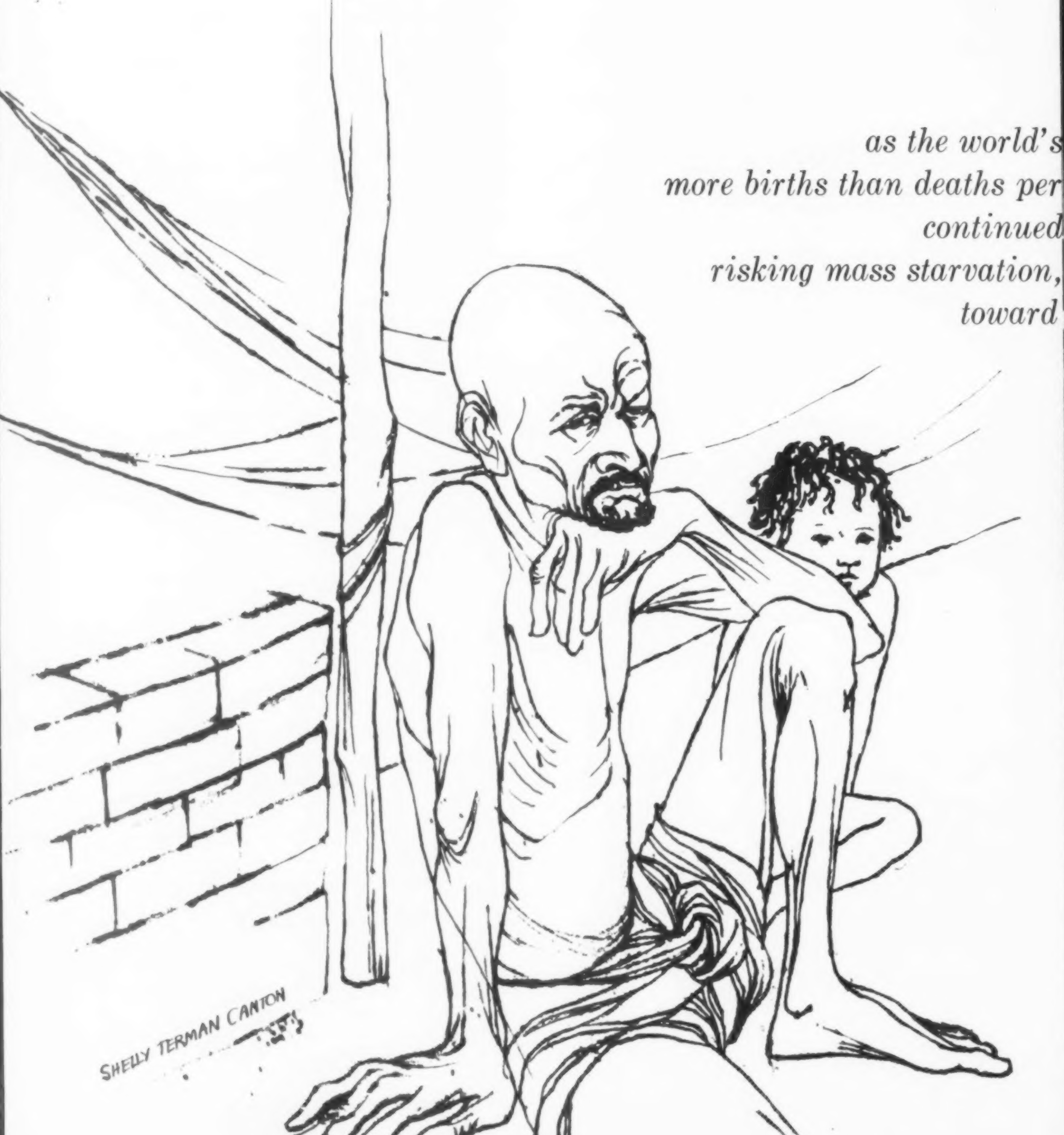
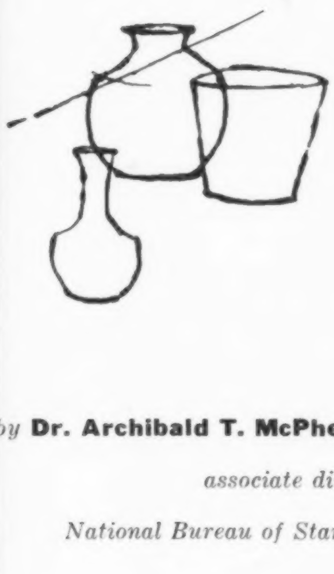


● The major problem facing science and technology today is supplying sufficient and adequate food for the world's explosive increase in population. This increase, at a rate unprecedented in the history of mankind, has come about largely through advances in sanitation and through the elimination of infectious diseases.

population explodes at the rate of 5,600
hour, two alternatives exist:
reliance upon agriculture, thereby
or accelerated research

THE SYNTHESIS OF FOOD

● The great reduction of the death rate has not been accompanied by a proportionate decrease in the birth rate. The population of the world has increased from 2.5-billion in 1950 to 2.7-billion in 1955, and 2.9-billion in 1960. United Nations experts estimate that the population will grow to 3.8-billion by 1975 and 6.3-billion by 2000.



by **Dr. Archibald T. McPherson,**
associate director,
National Bureau of Standards

● The current surplus of food in the United States, viewed in the perspective of history, is an unusual and transitory phenomenon. In most other parts of the world a great deal of attention is being given to means of increasing the supply of food. New crop lands are being opened up; yields are being increased by better seeds, improved cultivation, and the extensive use of synthetic fertilizer; the ocean's harvest is being stepped up; losses of food from plant and animal diseases and parasites are being checked; and better methods of transporting, storing, and preserving food are being instituted. These and other measures are bringing about a signif-

The total energy represented by the food consumed by all the people of the world amounts to only about 13 wood, and water power. These materials,

icant increase in the world's supply of food, and undoubtedly will continue to do so in the critical years ahead. Even with the large increase in population the *per capita* production of food in the world, exclusive of mainland China, was 7% higher in 1959-60 than in 1953-54.

Agriculture is inadequate

The increase in food production, however, cannot keep ahead of the increase in population for many years. New crop lands and increases in yields have definite limits; under the law of diminishing returns, the production of food by agriculture will approach a limit asymptotically. The population, on the other hand, is increasing at an accelerating rate and the profound social forces necessary to effect a large decrease in birth rate will be slow in coming about. There is no present prospect that the world population can be kept within the limitation of the food supply that can be provided by agriculture. The situation is rendered doubly serious by the fact that the peoples of the emerging nations of Asia even now are underfed and undernourished.

In the face of the approaching crisis, one alternative is to continue to depend only on agriculture. But even with maximum agricultural production, the inevitable shortage of food can lead only to major war, mass starvation, or both.

The other alternative is to mobilize the world's scientific and engineering resources for an operation of unparalleled but not impossible magnitude in the chemical production of food by direct synthesis and by the use of biochemical methods. Since potential raw materials are available in abundance, this operation can lead to such a great improvement in quality and increase in quantity of food that it not only could meet the present emergency but also could usher in a new era of civilization in which man increasingly would be freed from his dependence on plants and animals.

Prior to the advent of agriculture some 9,000 years ago, the earth was populated with only one or two people to the square mile in the more favored regions. The total population of the world probably was of the order of one million. The development of agriculture permitted a great increase in population so that several hundred people could subsist on a square mile of fertile land. Agriculture has made our present civilization possible.

Yet the fact that agriculture has served man so well during the past 9,000 years is no reason why he should continue to depend solely on it. The development of man-made food holds promise of as great an advance in civilization as that which was brought about by the discovery of agriculture.

If it grows, we can make it

Chemistry can make as great a contribution to civilization in the next hundred years as agriculture did in the preceding 9,000. This bold statement is based on the fact that the chemist already has produced from non-living materials most if not all of the substances essential to human nutrition. Furthermore, some of these substances —notably a number of vitamins and two of the essential amino acids—already are being manufactured in relatively large tonnages.

Other products, once available only from plant or animal sources, such as dyestuffs, resins, plastics, rubber, and fibers, now are synthesized in wide ranges of kinds and types. These synthetic materials are either competitive with or have largely displaced the natural products.

In general, chemists can make any substance that can be grown by plant or animal, and often can produce it more quickly and at lower cost than the natural product. Furthermore, natural products often are limited in availability, but synthetic materials can be made in quantities limited only by demand.

In the United States at least 99% of dyes are made synthetically, and about 97% of resins and plastics. In 1960, 73% of soaps and detergents were synthetic, up from 59% five years previously. About 69% of new rubber used in the United States in 1960 was synthetic as compared with 42% for 1955. Natural rubber still leads on a worldwide basis, however, with about 55% of the current total consumption.

The accomplishments of the synthetic chemist already have contributed significantly to the world food supply by freeing valuable crop lands that otherwise would have been used for growing alizarin, indigo, rubber, and the like. For example, the land that would have been required to grow the 1,778,000 metric tons of rubber used in 1960 would produce food for about 20-million people by present Asiatic standards.

A vast amount of experimental work has been done in separating, identifying, and synthesizing the constituents of food, and in determining the role of each in animal and human nutrition. Studies with both animals and human subjects have shown that it is possible to provide an adequate diet entirely from synthetic materials. The essential substances, however — vitamins, amino acids, fats, carbohydrates, colors, and flavors — differ widely in ease of synthesis and availability.

Man-made vitamins

The commercial production of vitamins has been a prime target for manufacturers because they offer a large return for the production of a relatively small quantity of material. A considerable proportion of the vitamins now on the market are made synthetically, and cost from \$6 to \$36 per kilogram (2.2 lbs).

The most expensive vitamin, per unit weight, is vitamin B_{12} at \$45 per gram (\$1,275 per ounce) for USP. This price, which has held for the past six months, is less than half what it was a year ago. But in spite of the high cost per unit weight, the daily requirement per person at the wholesale rate is less than two hundredths of a cent, because only two to four micrograms is needed.

Vitamin C, or ascorbic acid, probably is made in the largest tonnage of any of the vitamins. At the current market price of \$6.35 to \$6.60 per kilogram, the daily requirement per person of 75 milligrams would cost only 1/20th of a cent.

The effect of continued research on the production of vitamins is shown by the general reduction in price in recent years. In 1953 production in the United States amounted to 2.1-million kg at an average price of \$36.80 per kg, while five years later production was 4.4-million kg, and the price

percent of all energy obtained from oil, coal, gas, then, can feed the world.

was only $17.83 per kg. Thus production approximately doubled while price per unit quantity was cut in half.

All 22 amino acids have been synthesized

All 22 of the amino acids that go to make up plant and animal proteins have been synthesized. Particular attention has been paid to the eight amino acids that are termed essential because they are necessary to support life — valine, leucine, isoleucine, threonine, methionine, phenylalanine, lysine, and tryptophane.

Lysine and methionine are made in quantity for use as food supplements. Lysine is used as a supplement to the proteins in wheat, and currently is employed in bread and cereals as well as in feed for poultry and swine.

An article in April, 1959 estimated the market for lysine was about 100,000 lbs a year, and predicted a 50-fold increase if the price could be reduced from $6 a pound (the price at that time) to $1.50 or $2 a pound. It turned out, however, that the market increased even without a reduction in price since the price was $10 a pound at the end of 1960 and had fallen only to $6.95 for the monohydrochloride in mid-1961.

The principal use of methionine seems to be as a supplement to soybean protein in the feeding of swine and poultry. The feed grade of DL-methionine currently is quoted at $3.15 a kilogram, and the pharmaceutical grade at $9.92 a kilogram. By the use of methionine and other supplements it is now possible to produce 3-lb broilers with 25% less feed and in two weeks less time than formerly.

Fats and carbohydrates

The fats and the corresponding fatty acids in food products have been identified and synthesized. The availability from natural sources is such that fatty acids containing the higher numbers of carbon atoms, such as lauric, palmitic, stearic, and oleic acids, are produced commercially from plant or animal fats. Only the fatty acids containing the lower numbers of carbon atoms are made synthetically.

SCIENTIFIC *and engineering resources are being mobilized for the chemical production of food by direct synthesis and biological methods to provide the future needs of mankind. Chemists already have produced most of the essential substances for human nutrition from non-living materials. Among these substances are synthetic vitamins. A chemist is shown above as he checks the blending of ingredients used in the processing of vitamins. Properties of taste, color, and solubility are checked by another chemist (at left) at the Abbott Laboratories, North Chicago. Bottle-capping operations for another manmade substance, a synthetic sweetener, is shown below.*

Certain highly unsaturated fatty acids have been found essential in the feeding of animals, particularly linoleic and arachidonic acids. However, there is, as yet, insufficient evidence as to human requirements for essential fatty acids.

The simpler carbohydrates contained in food—particularly glucose, levulose, lactose, and sucrose—have been synthesized, but they are currently so readily available from natural sources that synthesis for commercial purposes has not been considered. However, the production of glucose by the hydrolysis of cellulose has been investigated extensively, and is said to have been employed under wartime conditions for making food.

The major problem in making glucose or other edible carbohydrates from wood or other plant products is primarily the problem of purifying the cellulose and utilizing the lignin and other non-cellulosic products to make the process economically feasible.

Pure cellulose is readily and quantitatively converted to glucose by simple acid hydrolysis. Glucose made in this way would be characterized as "manmade," rather than as synthetic, in keeping with the accepted nomenclature for rayon and other fibers made from cellulose.

Colors and flavors

Most of the colors and flavors used in the food processing industries as well as those sold for household use are made synthetically because they can be produced in greater variety and more cheaply than from natural sources.

To the discriminating taste, some of the synthetic flavors do not exactly match the natural flavors because only the major constituents have been synthesized. It would be possible to add all of the minor constituents and thereby duplicate natural flavors exactly, but the average consumer probably would not be willing to pay the added cost. In 1957 the production of colors and flavors in the United States was more than 45-million lbs at an average price of $1.38 per pound.

The color and flavor of food, while highly important, is nothing compared to the importance of securing an adequate supply of proteins for growth and maintenance of the body, and fats and carbohydrates for energy.

The body requires the essential amino acids of proteins in a definite proportion which may differ considerably from the proportion of these amino acids in the proteins of foods. Hence, if any one amino acid is deficient, it limits the utilization of the whole, and a human being could starve to death in an abundance of essential nutrients if only a single one should be lacking completely. This is the well-known law of the minimum which was first enunciated by Justus Liebig.

The daily caloric intake in the United States is far greater than that in Oriental countries — 3,000 or more calories as compared with 2,000 to 2,300. This difference is due in part to a much more liberal diet in the United States, but account also must be taken of a significant difference in body weight and of the fact that Asiatic peoples have a lower basal metabolism than Europeans.

Calories for a million people

In order to indicate the scope and magnitude of the synthetic industry that would be required to feed the increasing population of the world, the quantities of the principal materials that would be required to feed a million people for a year have been listed below:

These amounts have been derived from the recommendations of the Food & Nutrition Board of the National Academy of Sciences, National Research Council. For simplicity, use has been made of the average of the quantities recommended for adult men and adult women, and allowances for minerals, trace elements, and some vitamins have been excluded. The amounts for a total population would, of course, differ from those given in the table because of the different requirements for children and the aged. The figures given in the table are for an American population and are significantly greater —perhaps a third greater—than for an Oriental population.

26,500 tons of protein

The item in the table of greatest significance is the 26,500 metric tons of protein, which would be equivalent to approximately the same quantity of amino acids. The dietary allowance from which this amount of protein was computed was based on the assumption of an average dietary protein which is deficient in

ANNUAL DIETARY ALLOWANCES FOR A MILLION PEOPLE

Carbohydrates to supply 75% of calories	metric tons	205,300
Carbohydrates to supply 60% of calories	metric tons	164,250
Fats to supply 25% of calories	metric tons	30,400
Fats to supply 40% of calories	metric tons	48,700
Proteins	metric tons	25,550
Vitamins:		
Ascorbic acid	kilos	27,500
Vitamin A	million units	1,825,000
Vitamin B_{12}	grams	1,500
Vitamin D, irradiated ergosterol	million units	150,000
Niacin	kilos	7,665
Riboflavin	kilos	657
Thiamin	kilos	584

EDIBLE MUSHROOM *mycelium is being "grown" by a modified deep-vat fermentation technique at Battelle Memorial Institute, Columbus, Ohio. A synthetic nutrient medium is used to produce the spherical mycelial particles that can be "harvested" in 72 hours. Studies of this technique have ranged from those requiring laboratory-scale equipment to production on a commercial basis.*

some of the essential amino acids. If, however, the amino acids were supplied in the optimum proportion for utilization by the body, the quantity probably could be cut in half.

Fats required would amount to 30,400 to 48,700 metric tons, depending on whether 25% or 40% of the calories of the diet are to be derived from fat. The higher percentage of fat would correspond approximately to the Western diet, while the lower would probably be above that in Asiatic diets.

Carbohydrates would be needed in the largest quantity of any of the materials — 164,250 to 205,300 metric tons—depending on the balance between fats and carbohydrates as sources of calories for supplying energy.

Vitamin requirements would be small in tonnage, and would not represent a significant fraction of the cost if they were distributed as additives in other foods. Should they be distributed separately, however, the cost of distribution probably would exceed the cost of production.

Mineral requirements are highly important for adequate nutrition, but they are not shown in the table because the minerals needed are readily available and represent only negligible cost. Like vitamins, minerals could be distributed readily as additives.

There's food in the air

The principal raw materials for the synthesis of amino acids would be petroleum or coal, nitrogen from the atmosphere, and sulfur from mineral sources. Nitrogen would be fixed as ammonia by combination with hydrogen, as is done now on a large scale in industry. The supply of nitrogen thus is unlimited.

The petroleum that would be needed — assuming two kilograms for each kilogram of amino acid produced — would amount to only one ten-thousandth of current production. The sulfur required would be negligible in comparison with quantities used for other purposes.

The production of fats would require only petroleum or coal. Again the amounts needed would be small in comparison with the use of coal and petroleum for fuel. As a matter of fact, the total energy represented by the food consumed by the entire population of the world amounts to only about 13% of all energy obtained from oil, coal, gas, wood, and water power.

The 205,300 metric tons of carbohydrate required per year for a million people on a high carbohydrate diet could be produced from 184,800 metric tons of pure cellulose, which in turn could be made from approximately twice that amount of wood.

This amount is small in relation to the wood available. The world production of roundwood is about 1,670-million cubic meters, which is equivalent to 600- to 800-million metric tons. The current waste in cutting this vast amount of wood is probably of the same order of magnitude as the wood that is recovered. Cellulose from this source could be converted to edible carbohydrate to feed millions of people.

A rough estimate of $1 to $2 per

IDEAS AND APPLICATIONS #5

A Bonus from the Military

Low cost helicopters for businessmen, completely dehydrated meals, and perishable food preserved without refrigeration are but a few of the benefits that taxpayers will derive from the billions of dollars being poured into research programs aimed at military defense.

At a meeting of the Aviation-Space Writers' Assn. in New York, Brig. Gen. Clifton F. Von Kann, Army aviation director pointed out that mass production methods required to supply the Army with more than 3,500 turbine-powered, four-passenger helicopters should mean that civilians can get one for less than $25,000 by 1964. The helicopters can be used by businessmen, or as air taxis and commuter transports, or for farm chores.

The Army Quartermaster Corps is working on a complete dehydrated meal, ready to serve and eat after being mixed with hot water. The same unit is studying a method for preserving perishable food without refrigeration. Instead of waiting for hours for a T-bone steak to thaw after storage in a freezer, the housewife will be able to reach up on the shelf and drop the steak into a broiler in a matter of minutes.

An oral insect repellent guaranteed to chase away mosquitos and flies but go unnoticed by humans, is under development by the Army Medical Corps. Military scientists also are working on an oral drug to combat malaria and nitrogen mustard treatment of cancer. New plastic tubing that can replace torn arteries in arms and legs already has been developed. ■

kilogram capacity per year would seem to be reasonable as the cost for plant and equipment to synthesize food for a million people. On this basis, the capital outlay would be of the order of a quarter to half a billion dollars (per million people capacity).

Such an expenditure is not overwhelming. By way of comparison, new chemical construction in the United States currently is more than $3-billion per year, or six to 12 times the rough cost estimate of facilities for producing food for a million people.

To extend this estimate to 50-million people—the present annual increase in world population — the cost probably would be considerably less than 50 times the amount for one million people, because of economies in increasing the scale of manufacture and in the replication of equipment.

The early implementation of a large-scale program of food production such as proposed here would require the coordinated effort of experts in nutrition, synthetic organic chemistry, chemical engineering, and economics, with the advice of social scientists and support from the principal governments of the world.

A great number and variety of problems are involved which, if pursued at the present rate of investigation, might be solved in one or two generations. Yet with full recognition of the present emergency, and with adequate support in manpower, materials, and funds, practical solutions of the more pressing problems could be found while production was getting under way.

Two major lines of inquiry need to be pursued—one in nutrition and the other in chemistry. In nutrition there is need for a great deal more quantitative research on the components of an optimum diet as influenced by age, sex, race, and previous nutritional history. Life and growth can be maintained by diets in which the proportions of proteins, fats, carbohydrates, vitamins, and minerals vary widely, but often more of some foods are consumed than otherwise would be necessary to obtain certain critical substances that are in limited supply.

In this connection research is needed particularly on widespread dietary deficiencies in certain countries since small additions to the diet, as in the form of amino acid supplements, might extend the present food supplies even before major synthetic production can be accomplished.

The conduct of research in nutrition can be speeded up greatly by the application of modern statistical methods which makes it possible to study the effect of several different variables simultaneously. Progress was often quite slow in much of the pioneer work on nutrition because only one factor was varied at a time, keeping all else constant.

Methods of synthesis and the conduct of pilot plant studies would have to be investigated in order to develop the most economical large-scale manufacturing processes. Particular attention necessarily would be directed to the production of

IDEAS AND APPLICATIONS #6

Source Code Conference Technique

Procurement of equipment spare parts at government-contractor conferences can be speeded with a novel application of closed-circuit television that enables conference members to view the same equipment drawing simultaneously. The new technique will save approximately $4,500 per meeting in preparation costs, time, and manpower requirements.

The system was developed by the Logistics Engineering Component of the Heavy Military Electronics Dept., General Electric Co., primarily for Source Code Conferences held to determine equipment maintenance requirements. The closed-circuit television technique reduces the need for costly reproduction of hundreds of drawing prints and eliminates delays caused by circulating each print individually to conference members.

During the meetings, which sometimes last six to eight weeks, drawings of all piece parts, assemblies, sub-assemblies, and components incorporated in the equipment are reviewed and applicable codes assigned.

Equipment drawings are photographed on 35 mm film to standardize their size and facilitate handling. The film is mounted in a punched aperture card for either manual or automatic filing. A modified commercial projector combined with a rear-view screen, accepts the aperture card and enlarges the microfilmed drawing to approximately an 18-in. image. The image then is televised by a remotely controlled camera and relayed by video coaxial cable to monitors positioned throughout the conference area. ■

amino acids because of their critical role in nutrition. Not only is it necessary to develop new and more economical methods of synthesis, but practical means of producing the desired optical isomer must be discovered.

Since the amino acid molecule is characterized by an asymmetric carbon atom, the synthesis of an amino acid from inactive material yields equal amounts of dextro and laevo forms. When this racemic mixture is used in feeding experiments, the isomer which occurs in natural protein, of course, is readily utilized, and some animals can utilize the unnatural isomer of some amino acids.

The human organism, however, cannot use the unnatural isomer very effectively, and with some amino acids it might even be harmful. Hence it would be necessary either to synthesize a racemic mixture and separate the natural isomer, or to employ biosynthetic or other as yet undiscovered means of producing the wanted isomer.

L-lysine, now extensively used to increase the efficiency of the proteins in bread, is made both by a fermentation process with the use of microorganisms, and by chemical synthesis followed by the separation of the isomers. The latter process yields a product containing 95% L-lysine.

The acceptance of manufactured food

A secondary, but important, field in which research and development would be needed is organoleptics, considered broadly to include not only odor and taste but also color, texture, and consistency. The duplication of the odor and taste of natural foods is difficult because the senses are extremely sensitive and vary widely from one person to another.

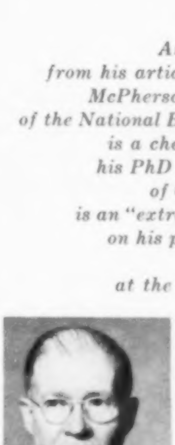
Texture and consistency also are important in determining the acceptability of foods. Fortunately, polymer science has uncovered the general principles for making substances with different structures and molecular weights so as to be either syrupy, gel-like, elastic, tough, brittle, or fibrous, as desired.

In addition to the development of a high degree of palatability, the successful introduction of synthetic food will require an educational campaign to present a correct picture of human nutrition and to combat superstition and prejudice. In the United States, thanks to cartoonists, columnists, and science fiction writers, any mention of synthetic food immediately conjures a picture of food pills, despite the obvious fact that synthetic food would be required in the same basic quantity as natural food.

Furthermore, it is necessary to combat propaganda of commercial interests and faddists who promote the long-outmoded theory that there is some vital property inherent in plant or animal products not present in the same substances when made by chemical synthesis from non-living materials.

A synthetic food industry

The development of a large-scale synthetic food industry would follow different patterns in different countries depending on the present food and population balance, agricultural capabilities, industrial resources, trade relations, and various other factors. In practically all countries, however, a first step is the production of amino acids, particularly lysine and methionine, to provide a more adequate diet by supplementing the incomplete proteins of the staple foods such as wheat, corn, rice, and millet.



As might be suspected from his article, Dr. Archibald T. McPherson, associate director of the National Bureau of Standards, is a chemist, having earned his PhD from the University of Chicago. This article is an "extracurricular" activity on his part and is in no way related to his work at the Bureau, where he is in charge of testing calibration, and specifications. A career member of the staff, he was first appointed during World War II. He has engaged in research in several fields, including organic chemistry, gas chemistry, dielectrics and electrical insulation, rubber, and high polymers. He also is chairman of the board of U.S. Civil Service Examiners at the Bureau. Active in professional scientific societies, he is a past president of the Washington Academy of Sciences. McPherson received his bachelor's degree from Trinity University and his master's from the University of Texas. He was an instructor in chemistry at Ewing Christian College in Allehabad, India, for two years.

Vitamins also are needed as dietary supplements in many countries, but the amounts required are relatively small in tonnage so it probably would be more economical to produce the entire world's supply in a few of the highly industrialized countries and ship them where they are needed.

Some of the more advanced nations might find it adequate to produce synthetic products for the enrichment of human diet and the more efficient feeding of farm animals. At the other extreme, countries which are experiencing acute population pressure might undertake simultaneously the production of amino acids, fats, and edible carbohydrates, and might expand the synthetic industry in a way that would most effectively supplement agricultural production.

Some industrial nations now dependent on imports for much of their food supply might undertake to develop a well-rounded synthetic food industry that not only would render them self-sufficient, but also would provide a surplus for export.

The future without agriculture

The progress of synthetic organic chemistry in the past 100 years indicates that synthetic foods ultimately will be developed to the point where they can be produced in such large quantities at so small an expenditure of human effort that they will replace agricultural products. The development will follow the same pattern as synthetic dye, resin, rubber, and fiber, which have replaced or now are rapidly replacing the same or similar materials formerly derived from plants or animals. Already a number of vitamins and two critically important amino acids are being manufactured commercially.

It is important that the world's governments be informed of the enormous possibilities of synthetic food so that they can undertake and accomplish large-scale production in time to meet the approaching population crisis. In the brief span, historically speaking, of 9,000 years, the practice of agriculture has made possible a thousand-fold increase in world population, at the same time providing the basis for civilization. The advent of a new and potentially much more efficient method of food production can permit a radical increase in world population, and may usher in a new era of civilization. ■

THE I·R DICTIONARY

for technical management

EDITOR'S NOTE: *The I·R Dictionary each issue is concerned only with technical terms used in the articles of that issue.*

alizarin — a reddish dye substance originally obtained from the madder plant, but now made from anthraquinine. One of the earliest known dyes, alizarin was synthesized in 1869 by Karl Graebe, of Germany, and William Henry Perkin, of England, within a few days of each other. The name alizarin came from Arabic words meaning "the juice."

amino acids — organic compounds formed by the reaction of water and proteins. Amino acids are the basic constituents of proteins, most important constituents of the living cell. Of the 22 amino acids that occur in most proteins, eight are essential to support life: leucine, isoleucine, threonine, valine, methionine, phenylalanine, lysine, and tryptophane. All of the 22 amino acids now have been synthesized.

asymptote—a straight line that is the limit of a tangent to a curve, as the point of contact recedes indefinitely along an infinite branch of the curve. In the circle and the ellipse, where there are no infinite branches, there is no real asymptote.

cybernetics—the science dealing with the interrelation between man and machine: the control and communication systems of the human nervous system and brain, as related to the mechanical-electrical communication systems of machines such as computers. MIT mathematician Norbert Wiener, acknowledged father of this branch of study, named it "cybernetics" from the Greek word for "helmsman."

cyborg—a combined word (cybernetic organism) coined by Dr. Manfred Clynes and Dr. Nathan Kline, Rockland State Hospital, Orangeburg, N.Y., to describe a machine-animal. A cyborg is a body on which machines are hitched or built into to perform or modify some of the body's functions.

$e = mc^2$ — the mathematical equation for Albert Einstein's special theory of relativity relating mass and energy. "E" represents energy in ergs, "m" represents mass in grams, and "c" represents the speed of light in centimeters per second. Einstein showed that mass and energy are interchangeable. The atom bomb is an example of the conversion of mass to energy.

Explorer I—the first artificial earth satellite placed successfully into orbit by the United States on Jan. 31, 1958. The satellite is 80 in. long, weighs 30.8 lbs, and carries a payload of 18 lbs of scientific instruments. It is expected to stay in orbit for more than five years. The Van Allen radiation belt was discovered by the Explorer's instruments. Advanced Explorer vehicles have been launched successfully in subsequent years.

hydrolysis—a chemical reaction in which water acts upon another substance to form one or more entirely new substances. An example of hydrolysis is the conversion of starch to glucose by water in the presence of a suitable catalyst.

indigo—a dark blue natural dye substance from the indigo plant. Indigo was synthesized in 1880 by German chemist Adolph von Baeyer, and the dye now is chiefly made synthetically from aromatic amino compounds.

isomers—molecules which contain the same number and kinds of atoms but differ in structure.

lignin—an organic substance related to cellulose, with which it forms the chief part of woody tissue.

organoleptics—a scientific study of the factors affecting or making an impression upon an organ or the whole organism, and embracing the senses of smell, taste, and sight.

PERT — an acronym for Program Evaluation Research Test, which later was renamed Program Evaluation and Review Technique when the system became operational. PERT is an advanced management system using a statistical approach to provide program managers with instant accurate information in the achievement of program objectives. The

PERT system originally was applied in 1958 by the Navy, Lockheed Aircraft Corp., and Booz, Allen & Hamilton.

proteins — molecules which are the principal substance of living cells. Proteins are composed of naturally occuring complex combinations of amino acids containing carbon, hydrogen, nitrogen, oxygen, and usually sulfur. The word protein is derived from a Greek word meaning "of first importance."

quantum theory—a theory, developed in 1900 by German physicist Max Karl Ernst Ludwig Planck, that radiation consisted of discrete bundles of energy, just as matter was made up of atoms, and that the process of emission or absorption of energy by atoms or molecules is not continuous but takes place by steps. Planck called the unit of radiation the "quantum," a word derived from the Latin word for "how much." Planck's quantum theory eventually explained the behavior of atoms, the electrons in atoms, and of nucleons in the atoms' nuclei. He was awarded the Nobel Prize in physics in 1918 for this theory.

racemic mixture — isomerism, or compounds formed by the union of two optically different forms, dextrorotatory (turning the plane of polarized light clockwise, or to the right) and levorotatory (turning counter-clockwise).

reliability systems—a term coined by Maj. Gen. Leslie E. Simon (ret.), former assistant chief of Ordnance R&D, to cover a hybrid system of statistical quality control, engineering, and management. The system was devised by Simon and others in the Army Ordnance Corps as a necessity to getting the Nike missile operational.

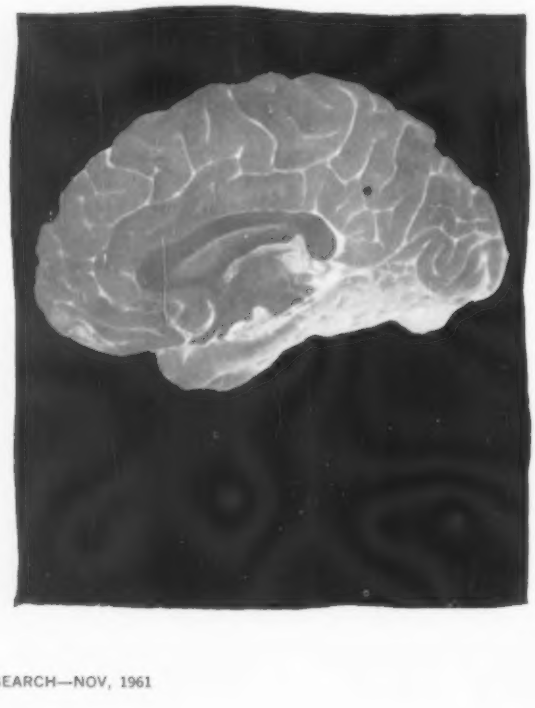
servomechanism—a system whose output is compared with its input in order that error between the two quantities may be controlled in a prescribed manner. Implicit in the definition is the notion of a follow-up activity in which the output is forced to be a preassigned function of the input.

Vanguard I — an earth satellite launched by the U.S. on March 17, 1958. Weighing 3.25 lbs, Vanguard I has an expected lifetime of up to 100 years in space. Vanguard II, a 20.7-lb satellite was launched Feb. 17, 1959, in the first attempt to measure the earth's cloud cover. Other Vanguard vehicles have been launched subsequently.

vitamin—a constituent of food in its natural state, essential for the normal nutrition of animals. In 1912, Polish-born biochemist Casimir Funk extracted a compound from yeast that proved effective in combating beri-beri. Because the compound proved to be an amine, Funk named it "vitamine," a Latin word for "life amine." The "e" was dropped from the end of the word later when it was discovered that not all vitamins are amines. ■

THE EVOLUTIONARY CYCLE FROM MAN TO MACHINE

by **Arthur C. Clarke,** *scientist and novelist*



ABOUT A MILLION YEARS AGO, an unprepossessing primate discovered that his forelimbs could be used for other purposes besides locomotion. Objects like sticks and stones could be grasped, and, once grasped, were useful for killing game, digging up roots, defending or attacking, and a hundred other jobs. On the third planet of the Sun, tools had appeared, and the place would never be the same again.

The first users of tools were *not* men—a fact appreciated only in the last year or two — but prehuman anthropoids, and by their discovery they doomed themselves. For even the most primitive of tools, such as a naturally-pointed stone that happens to fit the hand, provides a tremendous physical and mental stimulus to the user. He has to walk erect; he no longer needs huge canine teeth—since sharp flints can do a better job—and he must develop manual dexterity of a high order. These are the specifications of Homo sapiens; as soon as they start to be filled, all earlier models are headed for rapid obsolescence. To quote Professor Sherwood Washburn of the University of California's Anthropology Department: "It was the success of the simplest tools that started the whole trend of human evolution and led to the civilizations of today."

Note that phrase — "the whole trend of human evolution." The old idea that man invented tools is therefore a misleading half-truth; it would be more accurate to say that tools invented man. They were very primitive tools, in the hands of creatures who were little more than apes. Yet they led to us, and to the eventual extinction of the apemen who first wielded them.

Machina ex Deux

Now the cycle is about to begin again, but neither history nor prehistory ever exactly repeats itself, and this time there will be a fascinating twist in the plot. The tools the apemen invented caused them to evolve into their successor, Homo sapiens. The tool we have invented *is* our successor. Biological evolution has given way to a far more rapid process—technological evolution. To put it bluntly and brutally, the machine is going to take over.

This, of course, is hardly an original idea. That the creations of man's brain might one day threaten and perhaps destroy him is such a tired old cliché that no self-respecting science-fiction magazine would care to use it. It goes back, through

Capek's *R.U.R.*, Samuel Butler's *Erewhon*, Mary Shelley's *Frankenstein* and the Faust legend, to the mysterious but perhaps not wholly mythical figure of Daedalus, King Minos' one-man Office of Scientific Research. For at least three thousand years, therefore, a vocal minority of mankind has had grave doubts about the ultimate outcome of technology. From the self-centered, human point of view, those doubts are justified. But that, I submit, will not be the only—or even the most important—point of view for much longer.

When the first large-scale electronic computers appeared some fifteen years ago, they were promptly nicknamed "Giant Brains"—and the scientific community, as a whole, took a poor view of the designation. But the scientists objected to the wrong word. The electronic computers were not *giant* brains; they were dwarf brains, and they still are, though they have grown a hundred-fold within less than one generation of mankind. Yet even in their present flint-ax stage of evolution, they have done things which not long ago almost everyone would have claimed to be impossible — such as translating from one language to another, composing music, and playing a fair game of chess. And much more important than any of these infant *jeux* is the fact that they have breached the barrier between brain and machine.

Humanity's final issue

This is one of the greatest—and perhaps one of the last — breakthroughs in the history of human thought, like the discovery that the Earth moves round the Sun, or that man is part of the animal kingdom, or that $E = mc^2$. All these ideas took time to sink in, and were fanatically denied when first put forward. In the same way it will take a little while for men to realize that machines cannot only think, but may one day think men off the face of the Earth.

At this point you may reasonably ask: "Yes—but what do you mean by *think?*" I propose to side-step that question, using a neat device of the English mathematician A. M. Turing. Turing imagined a game played by two teletype operators in separate rooms — this impersonal link being used to remove all clues given by voice, appearance, and so forth. Suppose that one operator was able to ask the other any questions he wished, and the other had to make suitable replies. If, after some hours or days of this conversation, the questioner could not decide whether his telegraphic acquaintance was human or purely mechanical, then he could hardly deny that he/it was capable of thought. An electronic brain that passed this test would, surely, have to be regarded as an intelligent entity. Anyone who argued otherwise would merely prove that he was less intelligent than the machine; he would be a splitter of nonexistent hairs, like the scholar who proved that the *Odyssey* was not written by Homer, but by another man of the same name.

We are still decades — but not centuries—from building such a machine, yet already we are sure that it could be done. If Turing's experiment is never carried out, it will merely be because the intelligent machines of the future will have better things to do with their time than conduct extended conversations with men. I often talk with my dog, but not for long.

The transcendental machine

The fact that the great computers of today are still high-speed morons, capable of doing nothing beyond the scope of the instructions carefully programed into them, has given many people a spurious sense of security. No machine, they argue, can possibly be more intelligent than its makers—the men who designed it, and planned its functions. It may be a million times faster in operation, but that is quite irrelevant. Anything and everything that an electronic brain can do must also be within the scope of a human brain, given sufficient time and patience. Above all, no machine can show originality or creative power or the other attributes which are fondly labeled "human."

The argument is wholly fallacious; those who still bring it forth are like the buggy-whip makers who used to poke fun at stranded Model Ts. Even if it were true, it could give no comfort, as a careful reading of these remarks by Dr. Norbert Wiener will show: "This attitude [the assumption that machines cannot possess any degree of originality] in my opinion should be rejected entirely. . . . It is my thesis that machines can and do transcend some of the limitations of their designers. . . . It may well be that in principle we cannot make any machine, the elements of whose behavior we cannot comprehend sooner or later. This does not mean in any way that we shall be able to comprehend them in substantially less time than the operation of the machine, nor even within any given number of years or generations. . . . This means that though they are theoretically subject to human criticism, such criticism may be ineffective until a time long after it is relevant."

In other words, even machines *less* intelligent than men might escape from our control by sheer speed of operation. And, in fact, there is every reason to suppose that machines will become much more intelligent than their builders, as well as incomparably faster.

Inorganic intelligence

There are still a few authorities who refuse to grant any degree of intelligence to machines, now or in the future. This attitude shows a striking parallel to that adopted by the chemists of the early Nineteenth Century. It was known then that all living organisms are formed from a few common elements—mostly carbon, hydrogen, oxygen and nitrogen —but it was firmly believed that the materials of life could not be made from "mere" chemicals alone. There must be some other ingredient — some essence or vital principle, forever unknowable to man. No chemist could ever take carbon, hydrogen and so forth and combine them to form any of the substances upon which life was based. There was an impassable barrier between the worlds of "inorganic" and "organic" chemistry.

This *mystique* was destroyed in 1828, when Wöhler synthesized urea, and showed that there was no difference at all between the chemical reactions taking place in the body and those taking place inside a retort. It was a terrible shock to those pious souls who believed that the mechanics of life must always be beyond human understanding or imitation. Many people are equally shocked today by the suggestion that machines can think, but their dislike of the situation will not alter it in the least.

2nd generation of computers

Since this is not a treatise on computer design, you will not expect me to explain how to build a thinking machine. In fact, it is doubtful if any human being will ever be able to do this in detail, but one can indicate the sequence of events that will lead from H. sapiens to M. sapiens. The first two or three steps on the road have already been taken; machines now

exist that can learn by experience, profit from their mistakes and—unlike human beings — never repeat them. Machines have been built which do not sit passively waiting for instructions, but which explore the world around them in a manner which can only be called inquisitive. Others look for proofs of theorems in mathematics or logic, and sometimes come up with surprising solutions that had never occurred to their makers.

These faint glimmerings of original intelligence are confined at the moment to a few laboratory models; they are wholly lacking in the giant computers that can now be bought by anyone who happens to have a few hundred thousand dollars to spare. But machine intelligence will grow, and it will start to range beyond the bounds of human thought as soon as the second generation of computers appears—the generation that has been designed, not by men, but by other, "almost intelligent" computers. And not only designed, but also built—for they will have far too many components for manual assembly.

It is even possible that the first genuine thinking machines may be *grown* rather than constructed; already some crude but very stimulating experiments have been carried out along these lines. Several artificial organisms have been built which are capable of rewiring themselves to adapt to changing circumstances. Beyond this there is the possibility of computers which will start from relatively simple beginnings, be programed to aim at specific goals, and search for them by constructing their own circuits, perhaps by growing networks of threads in a conducting medium. Such a growth may be no more than a mechanical analogy of what happens to every one of us in the first nine months of our existence.

Complexity of intelligence

All speculations about intelligent machines are inevitably conditioned—indeed, inspired—by our knowledge of the human brain, the only thinking device currently on the market. No one, of course, pretends to understand the full workings of the brain, or expects that such knowledge will be available in any foreseeable future. (It is a nice philosophical point as to whether the brain can ever, even in principle, understand itself.) But we do know enough about its physical structure to draw many conclusions about the limitations of "brains" — whether organic or inorganic.

There are approximately ten billion separate switches—or neurons—inside your skull, "wired" together in circuits of unimaginable complexity. Ten billion is such a large number that, until recently, it could be used as an argument against the achievement of mechanical intelligence. About ten years ago a famous neurophysiologist made a statement (still produced like some protective incantation by the advocates of cerebral supremacy) to the effect that an electronic model of the human brain would have to be as large as the Empire State Building, and would need Niagara Falls to keep it cool when it was running.

This must now be classed with such interesting pronouncements as "No heavier-than-air machine will ever be able to fly." For the calculation was made in the days of the vacuum tube, and the transistor has now completely altered the picture. Indeed—such is the rate of technological progress today—the transistor itself is being replaced by still smaller and faster devices, based upon abstruse principles of quantum physics. If the problem were merely one of space, today's electronic techniques would allow us to pack a computer as complex as the human brain onto a single floor of the Empire State Building.

It's a tough job keeping up with science, and since I wrote that last paragraph the Marquardt Corporation's Astro Division has announced a new memory device which could store inside a six-foot cube *all information recorded during the last ten thousand years.* This means, of course, not only every book ever printed, but *everything* ever written in *any* language on paper, papyrus, parchment, or stone. It represents a capacity untold millions of times greater than that of a single human memory, and though there is a mighty gulf between merely storing information and thinking creatively—the Library of Congress has never written a book — it does indicate that mechanical brains of enormous power could be quite small in physical size. And the shrinkage is just gaining momentum, if I may employ such a mind-boggling phrase. Westinghouse now manufacturers a five-watt amplifier that could rather easily be mistaken for an aspirin tablet, and radio sets the size of lumps of sugar are also available. Before long, they will be the size not of lumps but of grains, for the slogan of the microminiaturization experts is "If you can see it, it's too big."

Components of the brain

Just to prove that I am not exaggerating, here are some statistics you can use on the next hi-fi fanatic who takes you on a tour of his installation. During the 1950s, the electronic engineers learned to pack up to a hundred thousand electronic components into one cubic foot. (To give a basis of comparison, a good hi-fi amplifier may contain two or three hundred parts, a domestic radio about a hundred.) Here at the beginning of the Sixties, the attainable figure is around a million electronic components per cubic foot; by 1970, when today's experimental techniques of microscopic engineering have begun to pay off, it may reach a hundred million.

Fantastic though this last figure is, the human brain surpasses it by a thousand-fold, packing its ten billion neurons into a *tenth* of a cubic foot. And although smallness is not necessarily a virtue, even this may be nowhere near the limit of possible compactness.

For the cells composing our brains are slow-acting, bulky, and wasteful of energy — compared with the scarcely more than atom-sized computer elements that are theoretically possible. The mathematician John von Neumann once calculated that electronic cells could be ten billion times more efficient than protoplasmic ones; already they are a million times swifter in operation, and speed often can be traded for size. If we take these ideas to their ultimate conclusion, it appears that a computer equivalent in power to one

human brain need be no bigger than a matchbox.

This slightly shattering thought becomes more reasonable when we take a critical look at flesh and blood and bone as engineering materials. All living creatures are marvelous, but let us keep our sense of proportion. Perhaps the most wonderful thing about life is that it works at all, when it has to employ such extraordinary materials, and has to tackle its problems in such roundabout ways.

As a perfect example of this, consider the eye. Suppose *you* were given the problem of designing a camera—for that, of course, is what the eye is—which *has to be constructed entirely of water and jelly*, without using a scrap of glass, metal or plastic. You're quite right; the feat is impossible. The eye is an evolutionary miracle, but it's a lousy camera. You can prove this while you're reading the next sentence. Here's a medium-length word: photography. Close one eye and keep the other fixed—repeat, *fixed*—on that center "g." You may be surprised to discover that, unless you cheat by altering the direction of your gaze, you cannot see the whole word clearly. It fades out three or four letters to the right and left.

No camera built—even the cheapest—gives as poor an optical performance as this. For color vision, also, the human eye is nothing to boast about; it can operate only over a small band of the spectrum. To the worlds of the infrared and ultraviolet, visible to bees and other insects, it is completely blind.

We are not conscious of these limitations because we have grown up with them, and indeed if they were corrected the brain would be quite unable to handle the vastly increased flood of information. But let us not make a virtue of a necessity; if our eyes had the optical performance of even the cheapest miniature camera, we would live in an unimaginably richer and more colorful world.

These defects are due to the fact that precision scientific instruments simply cannot be manufactured from living materials. With the eye, the ear, the nose—indeed, all the sense organs — evolution has performed a truly incredible job against fantastic odds. But it will not be good enough for the future; indeed, it is not good enough for the present.

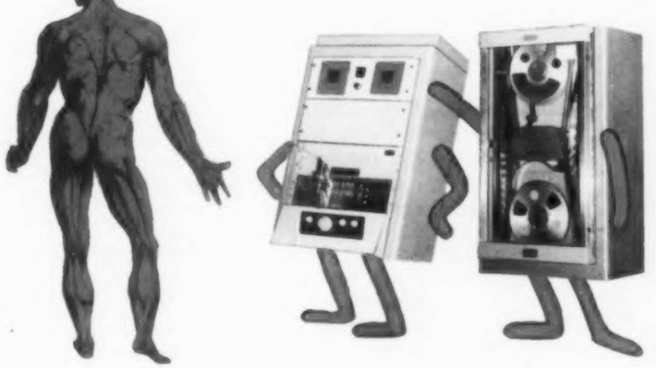
There are some senses that do not exist, that probably can never be provided by living structures, and which we need in a hurry. On this planet, to the best of our knowledge, no creature has ever developed organs that can detect radio waves or radioactivity. Though I would hate to lay down the law and claim that nowhere in the universe can there be organic Geiger counters or living TV sets, I think it highly improbable. There are some jobs that can be done only by vacuum tubes or magnetic fields or electron beams, and are therefore beyond the capability of purely organic structures.

The specs are rough

There is another fundamental reason why living machines such as you and I cannot hope to compete with nonliving ones. Quite apart from our poor materials, we are handicapped by one of the toughest engineering specifications ever issued. What sort of performance would you expect from a machine which has to grow several billionfold during the course of manufacture, and which has to be completely and continuously rebuilt, molecule by molecule, every few weeks? This is what happens to all of us, all the time; you are not the man you were last year, in the most literal sense of the expression.

Most of the energy and effort required to run the body goes into its perpetual tearing down and rebuilding, a cycle completed every few weeks. New York City, which is a very much simpler structure than a man, takes hundreds of times longer to remake itself. When one tries to picture the body's myriads of Conrad Hiltons and Bill Zeckendorfs all furiously at work, tearing up arteries and nerves and even bones, it is astonishing that there is any energy left over for the business of thinking.

Now I am perfectly well aware that many of the "limitations" and "defects" just mentioned are nothing of the sort, looked at from another point of view. Living creatures, because of their very nature,



"It looks great—but what can you expect from water and jelly?"

can evolve from simple to complex organisms. They may well be the only path by which intelligence can be attained, for it is a little difficult to see how a lifeless planet can progress directly from metal ores and mineral deposits to electronic computers by its own unaided efforts. But though intelligence can only arise from life, it may then discard it. Perhaps at a later stage, as the mystics have suggested, it also may discard matter; but this leads us into realms of speculations which an unimaginative person like myself would prefer to avoid.

One often-stressed advantage of living creatures is that they are self-repairing and can reproduce themselves with ease, indeed, with enthusiasm. This superiority over machines will be short-lived; the general principles underlying the construction of self-repairing and self-reproducing machines have already been worked out. There is, incidentally, something ironically appropriate in the fact that A. M. Turing, who pioneered in this field and first indicated how thinking machines might be built, shot himself a few years after publishing his results. It is very hard not to draw a moral from this.

Inaccessible universe

The greatest single stimulus to the evolution of mechanical — as opposed to organic — intelligence is the challenge of space. Only a vanishingly small fraction of the universe is directly accessible to mankind, in the sense that we can live there without elaborate protection or mechanical aids. If we generously assume that humanity's potential *Lebensraum* extends from sea level to a height of three miles, over the whole Earth, that gives us a total of some half billion cubic miles. At first sight this is an impressive figure, but it is absolutely nothing when set against the reaches of space. Our present telescopes, which are certainly not the last word on the subject, sweep a volume at least a million million million million million million million million million million times greater. Though such a number is, of course, utterly beyond conception, it can be given a vivid meaning. If we reduce the known universe to the size of the Earth, then the portion in which *we* can live without space suits and pressure cabins is about the size of a single atom.

It is true that, one day, we are going to explore and colonize many other atoms in this Earth-sized volume, but it will be at the cost of tremendous technical efforts, for most of our energies will be devoted to protecting our frail and sensitive bodies against the extremes of temperature, pressure, or gravity found in space and on other worlds. Within very wide limits, machines are indifferent to these extremes. Even more important, they can wait patiently through the years and the centuries that will be needed for travel to the far reaches of the universe.

Like many other qualities, intelligence is developed by struggle and conflict; in the ages to come, the dullards may remain on placid Earth, and real genius will flourish only in space—the realm of the machine, not of flesh and blood.

A striking parallel to this situation already can be found on our planet. Some millions of years ago, the most intelligent of the mammals withdrew from the battle of the dry land and returned to their ancestral home, the sea. They are still there, with brains larger and potentially more powerful than ours. But (as far as we know) they do not use them; the static environment of the sea makes little call upon intelligence. The porpoises and whales, who might have been our equals and perhaps our superiors had they remained on land, now race in simple-minded and innocent ecstasy beside nuclear-powered sea monsters carrying sixteen megatons of death. Perhaps they, not we, made the right choice, but it is too late to join them now.

Whither H. sapiens?

If you have stayed with me so far, the protoplasmic computer inside your skull should now be programed to accept the idea—at least for the sake of argument—that machines can be both more intelligent and more versatile than men, and may well be so in the very near future (probably before the end of the next century; no one can imagine *any* technical development that will take much longer than that). So it is time to face the question: "Where does that leave man?"

I suspect that this is not a question of very great importance—except, of course, to man. Perhaps the Neanderthalers made similar plaintive noises, around 100,000 B.C., when H. sapiens appeared on the scene, with his ugly vertical forehead and ridiculous protruding chin. Any Paleolithic philosopher who gave his colleagues the right answer would probably have ended up in the cooking-pot; I am prepared to take that risk.

The short-term answer may indeed be cheerful rather than depressing. There may be a brief Golden Age when men will glory in the power and range of their new partners. Barring war, this age lies directly ahead of us. As Dr. Simon Ramo put it recently: "The extension of the human intellect by electronics will become our greatest occupation within a decade." That is undoubtedly true, if we bear in mind that at a somewhat later date the word "extension" may be replaced by "extinction."

Electronic companions

One of the ways in which thinking machines will be able to help us is by taking over the humbler tasks of life, leaving the human brain free to concentrate on higher things. (Not, of course, that this is any guarantee that it will do so.) For a few generations, perhaps, every man will go through life with an electronic companion, which may be no bigger than today's transistor radio. It will "grow up" with him from infancy, learning his habits, his business affairs, taking over all the dull

Internationally acclaimed writer and novelist, Arthur C. Clarke is a fellow of the Royal Astronomical Society, and twice has been chairman of the British Interplanetary Society. He has engaged in underwater exploration and photography along the Australian Great Barrier Reef and the coast of Ceylon, where he now lives. Clarke has published nine novels, more than 200 articles and short stories, and 12 works of non-fiction. He was educated in England and graduated with high honors in physics and in pure and applied mathematics. Because of its interest to technical management, Clarke's article, "Machina ex Deux," is reprinted here by permission of the author and his agents, Scott Meredith Literary Agency Inc.

chores like routine correspondence and income tax returns. On occasion it could even take its master's place, keeping appointments he preferred to miss, and then reporting back in as much detail as he desired. It could substitute for him over the telephone so completely that no one would be able to tell whether man or machine was speaking: a century from now, Turing's "game" may be an integral part of our social lives, with complications and possibilities which I leave to the imagination.

You may remember that delightful robot, Robbie, from the movie *Forbidden Planet* (one of the three or four movies so far made that anyone interested in science-fiction can point to without blushing). I submit, in all seriousness, that most of Robbie's abilities—together with those of a better-known character, Jeeves—will one day be incorporated in a kind of electronic companion-secretary-valet. It will be much smaller and neater than the walking jukeboxes which Hollywood presents, with typical lack of imagination, when it wants to portray a robot. And it will be extremely talented, with quick-release connectors allowing it to be coupled to an unlimited variety of sense organs and limbs. It would, in fact, be a kind of general-purpose, disembodied intelligence that could attach itself to whatever tools were needed for any particular occasion. On one day it might be using microphones or electric typewriters or TV cameras; on another, automobiles or airplanes—or the bodies of men and animals.

Why not synthesize man and machine?

And this is, perhaps, the moment to deal with a conception which many people find even more horrifying than the idea that machines will replace or supersede us. It is the idea that they may combine with us.

I do not know who first thought of this: probably the physicist J. D. Bernal, who in 1929 published an extraordinary book of scientific predictions called *The World, the Flesh and the Devil*. In this slim and long-out-of-print volume (I sometimes wonder what the sixty-year-old Fellow of the Royal Society now thinks of his youthful indiscretion, if he ever remembers it), Bernal decided that the numerous limitations of the human body could be overcome only by the use of mechanical attachments or substitutes—until, eventually, all that might be left of man's original organic body would be the brain.

This idea is already far more plausible than when Bernal advanced it, for in the last few decades we have seen the development of mechanical hearts, kidneys, lungs, and other organs, and the wiring of electronic devices directly into the human nervous system.

Olaf Stapledon developed this theme in his wonderful history of the future, *Last and First Men*, imagining an age of immortal Giant Brains, many yards across, living in beehive-shaped cells, sustained by pumps and chemical plants. Though completely immobile, their sense organs could be wherever they wished, so their center of awareness—or consciousness, if you like—could be anywhere on Earth or in the space above it. This is an important point which we—who carry our brains around in the same fragile structure as our eyes, ears, and other sense organs, often with disastrous results—may easily fail to appreciate. Given perfected telecommunications, a fixed brain is no handicap, but rather the reverse. Your present brain, totally imprisoned behind its walls of bone, communicates with the outer world and receives its impressions of it over the telephone wires of the central nervous system—wires varying in length from a fraction of an inch to several feet. You would never know the difference if those "wires" were actually hundreds or thousands of miles long, or included mobile radio links, and your brain never moved at all.

In a crude way—yet one that may accurately foreshadow the future—we have already extended our visual and tactile senses away from our bodies. The men who now work with radioisotopes, handling them with remotely-controlled mechanical fingers and observing them by television, have achieved a partial separation between brain and sense organs. They are in one place, their minds effectively in another.

Cybernetic organisms

Recently the word Cyborg (cybernetic organism) has been coined to describe a machine-animal of the type we have been discussing. Doctors Manfred Clynes and Nathan Kline of Rockland State Hospital, Orangeburg, New York, who invented the name, define a Cyborg in these stirring words: "an exogenously extended organizational complex functioning as a homeostatic system." To translate, this means a body which has machines hitched to it, or built into it, to take over or modify some of its functions.

I suppose one could call a man in an iron lung a Cyborg, but the concept has far wider implications than this. One day we may be able to enter into temporary unions with any sufficiently sophisticated machines, thus being able not merely to control but to *become* a spaceship or a submarine or a TV network. This would give far more than purely intellectual satisfaction; the thrill that can be obtained from driving a racing car or flying an airplane may be only a pale ghost of the excitement our great-grandchildren may know, when the individual human consciousness is free to roam at will from machine to machine, through all the reaches of sea and sky and space.

But how long will this partnership last? Can the synthesis of man and machine ever be stable, or will the purely organic component become such a hindrance that it has to be discarded? If this eventually happens—and I have tried to give reasons why it must—we have nothing to regret, and certainly nothing to fear.

Machina benevolent

The popular idea, fostered by comic strips and the cheaper forms of science-fiction, that intelligent machines must be malevolent entities hostile to man, is so absurd that it is hardly worth wasting energy to refute it. I am almost tempted to argue that only *un*intelligent machines can be malevolent; anyone who has tried to start a balky outboard probably will agree. Those who picture machines as active enemies are merely projecting their own aggressive instincts, inherited from the jungle, into a world where such things do not exist. The higher the intelligence, the greater the degree of cooperativeness. If there is ever a war between men and machines, it is easy to guess who will start it.

Yet however friendly and helpful the machines of the future may be, most people will feel that it is a rather bleak prospect for humanity if it ends up as a pampered specimen in some biological museum—even if that museum is the whole planet Earth. This, however, is an attitude I find impossible to share.

No individual exists forever; why should we expect our species to be immortal? Man, said Nietzsche, is a rope stretched between the animal and the superhuman—a rope across the abyss. That will be a noble purpose to have served. ■

conventional machine tools

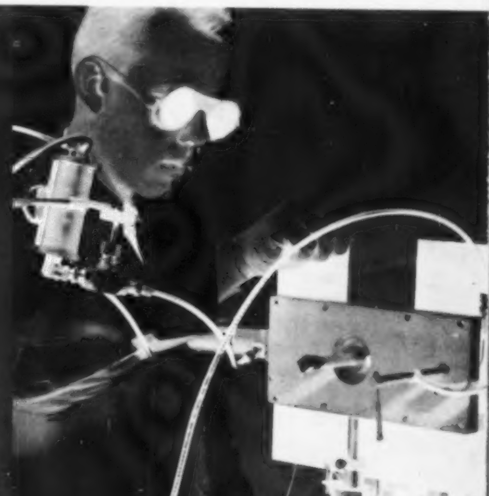
processing lines ordinarily

new product □ originality

breakthrough are introduce

tainty, over-taxed emotions

PLANNING TOMORROW'S PRODUCTION LINES



PRODUCT DESIGNERS *are more concerned with getting a new product idea to work than with making the product under strict cost limitations. The manufacturing research engineer must bring product and manufacturing technology together. Here an engineer tests light sensitive material.*

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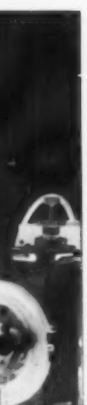


RESEARCH THAT ANTICIPATES how we will manufacture products in five or 10 years, as well as what those products will be, is one of the most critical needs in manufacturing. Technical management must start today to study and explore many new technologies so that economical and efficient manufacturing plants will be ready for the products of the future.

This new dimension of manufacturing research resembles product development. It permits years-ahead thinking. It examines a dozen possibilities in the hope of finding one technique that will speed assembly of future products. It works out mathematical rules for stabilizing high-speed servomechanisms. It spends months on techniques like electro-machining, electro-forming, and vacuum deposition because they may be the answers to working more difficult, but high-performance materials. It is thorough, painstaking, unhurried, analytical, and unfettered by prejudices, time limitations, or current problems. It works with product development in such a way that each influences the other's work.

Such a concept seeks to solve production problems before they occur. It aims at setting the plant stage for producing things still vague in the mind of the development engineer. It gathers information from the frontiers of electronics, optics, physics, chemistry, and every other physical science, and organizes the results for ready adoption by manufacturing engineers.

If laminations of metals and plastics are on the horizon, we ought to find out how such materials can be handled on the necessary process line. What properties will necessitate special handling or new techniques? What properties can be exploited? What new cutting, forming, or assembly techniques will be required? Are the etching, plating, cleaning, and joining compounds of today satisfactory, or should improved replacements be sought?

In general terms, this new dimension in manufacturing research closes the gap between product development and manufacturing. It hastens products into full capacity production, and it encourages the use of more advanced tools, techniques, and processes. The economic use, for instance, of high-speed, numerically-controlled machine tools demands extensive and thorough planning, cost comparison, experimentation. Without this, you often hear the complaint that the machine tool is not operating above the break-even point, or that it isn't flexible enough to adjust to changes in product requirements. In economic terms, the payoff will come in

by **Edward J. Garvey,**

manufacturing research director, General Products Div., International Business Machines Corp.

faster production set-up and lower cost per unit output as well as higher reliability.

Day-to-day solution only

Of the more than $14-billion spent annually on research in the United States, only a small percent is spent on study to improve manufacturing technology. At that, the millions going into manufacturing research are paying mostly for solutions to day-to-day problems.

It is unlikely that this situation will remain static. There is growing and significant pressure on production executives to slash production costs, improve reliability, and reduce new production line set-up time. In face of the rate at which new and improved products are pouring out of development research, the problem faced by operations management in accomplishing these three tasks is serious.

How, for instance, is management to improve unfamiliar chemical processes significantly when, by the time a new process is readied, the product it helps to make is replaced by something new requiring a different process? How are plants to make use of numerically-controlled machines in face of rapidly changing product requirements? Many companies employ a modular assembly line approach to permit fast and inexpensive retooling. But this is not the whole answer.

A limited approach

Manufacturing research as it is widely understood today constitutes a limited approach to the improvement of manufacturing techniques. In such an approach, experienced specialists in the various manufacturing technologies perform very necessary tasks of improving welding, painting, machining, chemical and metallurgical processing, assembly, testing, and materials handling. Faced with day-to-day and year-to-year manufacturing requirements, the department rarely breaks away from current problems to set up long-term planning and goals.

Thus manufacturing very often is caught between time limitations and staggering retooling and refitting tasks. Once a product development department releases new product plans to plant management, pressure is on for maximum production rates as soon as possible.

Manufacturing engineers invariably are forced to turn to time-honored methods of production. Conventional machine tools, conventional assembly techniques, and conventional processing lines are installed to produce the new product. Originality, innovation, and process breakthrough are introduced later in a frenzy of uncertainty, overtaxed emotions, and often-changed floor plans.

Manufacturing is subjected to drastic changes whenever new products are introduced. It was, in fact, the advent of transistorized computers that gave IBM its reason to instigate some manufacturing research techniques. While solid-state components brought about changes in computer performance, they also brought about serious changes in manufacturing requirement: they couldn't be put together the same way.

No blueprint for results

As with any research function, you cannot draw a five-year plan or projected financial statement indicating the rewards of blue-sky manufacturing research. But we do know now that, however difficult it may be to itemize research costs and results, well-directed development work has paid off in industry with new, better, and low-cost products.

This difficulty of projecting concrete results in specific dollar values means that management launches a manufacturing research group largely on faith. Yet top management alone has the power to create, equip, and back up such an organization. For manufacturing research serves no purpose unless it is in complete harmony with operating management and has the fiscal approval of financial management.

A problem of location

A research group is not wise to locate within a plant organization because it soon gets choked with current problems and immediate goals, is hampered by local budget reviews, and has insufficient stature to communicate with other research arms of the company.

In a large company, it also is unwise to locate a manufacturing research laboratory at corporate headquarters. It is too far from the influence of a plant and development laboratory to maintain proper perspective. Manufacturing research must have equipment available for model building, testing, and experimentation, usually available only in a manufacturing and development complex. In addition, manufacturing research needs to see and talk about what is going on in manufacturing and development. Proximity to these operations encourages an exchange

MANUFACTURING RESEARCH *searches in many directions. Physics, mechanics, optics, and electronics are major avenues that provide the answers to how products of the future will be made. Among new and ingenious manufacturing methods for space-age precision machine tools is the plastic bubble (left) used by the R. K. LeBlond Machine Tool Co., Cincinnati, during runoff and inspection of its new tape-turn lathes. The air-conditioned bubble, held up by air pressure, can maintain ideal temperatures for balancing operating characteristics of the lathe and its tape control system. Three engineers (right) review ideas on non-linear analysis in a search for new manufacturing methods at the IBM General Products Div.*

of ideas and opinions—a necessary flux for healthy research.

The ideal location and reporting level depends on the company. But it should be arranged so that the group has sufficient stature, adequate budget and facilities, and opportunity to work alongside plant and development laboratory management without becoming involved in day-to-day problems.

Selling the concept to management

Just how manufacturing research is sold to top management also depends on the company, its size, and the anticipated scope of the research that will be undertaken.

Selling an adequate program is no mean task in any corporation. Plans to set up any new and sizeable group violate management's natural and desirable hesitancy to allow the building of "empires" within the company. It also runs opposed to inertia. Indeed, advocates of manufacturing research themselves are suspect of bias if they are to benefit from the launching of a new laboratory.

Probably for the very reason that a bias can be ascribed to all quarters does management use the services of an independent consulting firm to investigate the value of setting up anything akin to a new research organization.

Early in the planning stages at IBM, for example, a competent engineering consultant was called in to offer advice on manufacturing research. The consultant's services proved fully valuable from several points. First, the consultant took an unprejudiced view in his study and recommendation. He also viewed company operations as one concerned only with fundamentals of an industrial enterprise. He could see, for example, whether manufacturing research activities would serve a basic function in future company operations.

This service very often is a necessary part of preparing a recommendation to company management. It is not, however, the entire job. No one should expect independent consultants to prepare the entire proposal. A consultant rarely is given enough time to study the total corporate picture as it might be affected by a proposal for a manufacturing research laboratory. A consultant rarely learns all the projected enterprises or requirements of plant and personnel. He rarely is allowed complete exposure to long-term budgets or product forecasting.

An inside study of needs

Since these things already are known within the company, it should be a study committee's task to gather this information, analyze it, and determine what the combination indicates in terms of a manufacturing research requirement.

At IBM, for example, a committee was organized at corporate headquarters with members drawn from manufacturing staff personnel. Additional members were recruited from the manufacturing engineering staffs of major plants. Each committee member gathered pertinent data and contributed to final recommendations. The committee also directed the work of the engineering consultant.

Written reports of such committees, however well they are documented, have their limitations. Most

serious is the ponderous detail that must be used to support a positive conclusion. In the complexities of logical reasoning, there is no drama or decisiveness to the answer to: "Will it work, or not?" For dramatic support of the conclusion, nothing succeeds as well as a live demonstration.

A pilot manufacturing research program started at Endicott, N.Y., under the wing of plant manufacturing engineering, provided the dramatic evidence. Fortunately, the pilot program was instituted with the advent of solid-state electronic computers, thus giving the group an ideal situation for demonstrating its ultimate function in a limited way.

How, where, and when

As soon as the pilot group was launched, it began to work with the development laboratory to determine where the solid-state packaging development was headed. It also looked at manufacturing throughout industry to find the most promising assembly techniques for solid-state electronics. Armed with this information, the group determined that standard modules of electronic circuitry would be economical and highly feasible for the first phase of solid-state computer technology. These standard modules or building blocks would enable manufacturing to reach higher levels of production and maintain reasonable unit costs.

Convinced of this, the pilot group sat down with development project engineers and asked for modular concepts in the design package. Meanwhile, manufacturing engineers were asked to draw plans for the necessary tooling, much of which was ultimately, if not immediately, automatically-controlled chemical processes and numerically-controlled assembly operations.

The pilot program group's contribution, then, was enough creative thinking to enable development engineers to meet with manufacturing engineers at product announcement time with many of the trouble spots already eliminated.

Results of the program certainly were dramatic. It took less time for the first solid-state computer (the IBM 1401) to be built in the plant following product announcement than it had taken for any of its data processing predecessors. And the solid-state computer represented a more sophisticated logical network than any of its predecessors.

Such a pilot program is useful because it demonstrates to management at all levels just what manufacturing research can do. It also enables advocates of manufacturing research to see how their initial plans may have to be redrafted.

Control at division level

Coincidental with the successful completion of the pilot program, IBM management organized its U.S. operations into strong, functional divisions. When the General Products Div.—one of two data processing development and manufacturing divisions, with four plant and two laboratory sites—was organized, it became evident that division level control offered many advantages for manufacturing research. Among these were unity of interest and ample support.

Because of the greatly varying product and manufacturing requirements of individual divisions, it was decided by corporate management that each division would be responsible for establishing adequate manufacturing research programs to meet its individual long-range needs. All programs, of course, must be effectively coordinated among divisions.

A division plan was then organized composed of ideas gained largely from the pilot program group at Endicott. A final proposal was drafted and, with modifications, was adopted by division management.

Points considered in the proposal included present and projected size and budget; location, facilities, and personnel; reporting level and coordination with other groups; scope and direction; and internal organization.

Edward J. Garvey began his career with IBM in 1939 as a student. While serving as manager of manufacturing engineering, he organized the pilot manufacturing research program at Endicott. In 1959, he was promoted to planning manager, and was named to his present post as director of manufacturing research in 1960. A graduate of Stevens Institute of Technology, Garvey has a degree in mechanical engineering. He is a member of the ASTME.


An Analogy to Ideation
The seed will achieve its fullest potential when nurtured in the most receptive environment.
So, too, ideas.
If your ideas need a place in the sun, we would like very much to hear from you.
FAIRCHILD
SEMICONDUCTOR
545 WHISMAN ROAD, MOUNTAIN VIEW, CALIF. • YORKSHIRE 8-8161 • TWX: MN VW CAL 853
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

The General Products Div. manufacturing research group was located at Endicott where the plant offered model shop and test equipment facilities as well as an opportunity to experiment "on line." However, the group reports directly to the division's assistant general manager in charge of manufacturing operations.

Liaison with all development project managers and local manufacturing engineering is maintained to keep abreast of current developments and their possible effect on future products. A manufacturing research board, representing division management, manufacturing engineering of each plant, and development engineering of each laboratory, meets regularly with the director of manufacturing research to review current progress, work scheduled, and long-term goals. The board makes recommendations as it thinks fit, but ultimate responsibility for direction and scope lies with the head of the manufacturing research function.

Building a sound foundation

The five years that passed while this organization, or one similar in function, was studied have paid off in two important ways. In this time, corporate management men had an opportunity to understand the purpose and potential of the proposed laboratory. Consequently, they were ready to accept the organization with all its physical requirements.

On the other side, we who now perform manufacturing research have had an opportunity to examine all sides of the proposal both in concept and detail. Thus our organization was able to incorporate all the valuable ideas considered in our studies and discard the poor ones.

We recognized, for instance, the advantages of implementation on the divisional level rather than at corporate or plant levels. We became aware of the staff competence required to create basically new manufacturing technology and advanced processes beyond what can be generated by the already established manufacturing engineering department. And we recognized the necessity of interplant participation and coordination to gain motivation and understanding for all phases of our work.

A good part of the success of any laboratory organization is dependent upon a sound foundation in valid concepts. This is as true of a manufacturing research laboratory as of any other open-end laboratory organization. ■

THE RESEARCH TRENDLETTER

Government Research
November, 1961

Dear Sir:

The federal government is funding more than 60% of the $14-billion national R&D budget, and the expenditure can be expected to continue. With the nation's economic growth and technical development geared to defense needs, the impact of government research is widespread. Government research is the subject of a special series of articles in Industrial Research, starting with "Can You Afford Government R&D Contracts?" on page 13.

information retrieval

As the November issue went to press, the National Aeronautics & Space Administration (NASA) started to let several major contracts for the study of information retrieval. With the increased volume of scientific information being disseminated, the information storage and retrieval problem is receiving increased attention (see I·R special section on Information Retrieval, Vol. 3, No. 2).

Reflecting the growing interest in information retrieval is a $300,000 grant by the National Institutes of Health and the National Science Foundation to the Institute for Scientific Information, 33 S. Seventeen St., Philadelphia, Pa., to study and develop a unified citation index for scientific information, including the publication of a genetics index. The index is expected to complement the Beilstein, Chemical Abstracts, and Biological Abstracts indexes, and is not intended as a substitute.

Another advanced research area receiving close scientific attention is quantum physics. Measurement Systems Inc., 53 Water St., South Norwalk, Conn., manufacturer of electro-optical and infrared equipment, is developing and manufacturing an extremely small quantum detector to be installed with a small electro-explosive device, under a contract awarded by the Naval Weapons Laboratory, Dahlgren, Va. Like the infrared detector which evolved out of military research, the quantum detector may find useful industrial application.

outer and inner space

A space capsule that will streak nearly a quarter of a million miles into space and land on the moon's surface to radio back to earth scientific data about the lunar structure is under development at Ford Motor Co.'s Aeronutronic Div., Newport Beach, Calif. (see photograph on page 47). To be developed under contract with NASA's Jet Propulsion Laboratory, the capsule will be transported by the Ranger spacecraft now under development at JPL's Pasadena, Calif., facility.

A prototype model of a rotating electrolytic cell that operates under weightless conditions is being readied by Battelle Memorial Institute, 505 King St., Columbus 1, Ohio, for evaluation by the Aerospace Medical Laboratory, Aeronautical Systems Div., Air Force Systems Command. The cell may provide a vital link in a workable chemical system that will convert an astronaut's breath into breathable oxygen during space voyages lasting up to two years.

The world's first submarine capable of cruising at a depth of almost three miles and made entirely of aluminum is under construction at Groton, Conn., by the Electric Boat Div., General Dynamics Corp., under a $2-million contract from Reynolds International Inc., a subsidiary of Reynolds Metals Co. Three years of research by Reynolds International, Southwest Research Institute, General Dynamics, Woods Hole Oceanographic Institution, and the Navy preceded the building contract. Reynolds will own the sub and Woods Hole will operate it as part of a research program sponsored by the Navy's Office of Naval Research, which has allocated $1-million to Woods Hole for advance procurement of instruments the sub will carry and for the first year's leasing and operation. To be known as the Aluminaut, the sub may become a forerunner of an entirely new generation of underwater craft.

military research

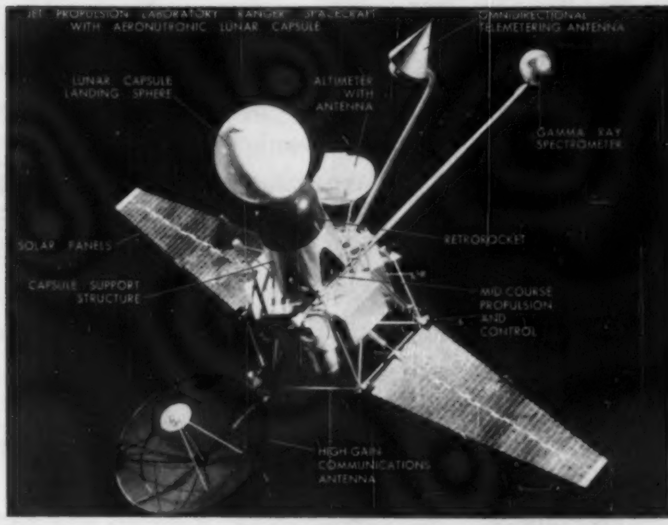
Research and development models of a new amphibious support vehicle are being built for the Navy by Lycoming Div., Avco Corp., Stratford, Conn., and FMC Corp., San José, Calif. Avco will produce a model using two submerged hydrofoils, under a $1,385,000 contract. FMC was awarded $1,158,000 to build a vehicle using a surface-piercing foil forward and a submerged foil aft. The craft will travel more than 35 knots on water and 25 mph on land, and will be used to transport cargo and assault troops.

Under sponsorship of the Army Ordnance Corps' Frankford Arsenal, Electro-Optical Systems Inc., 125 N. Vinedo Av., Pasadena, Calif., has developed an experimental device that will protect operators of optical equipment from nuclear flash blindness in the battlefield. The mechanism can close out the light from a nuclear flash in one ten-thousandth of a second, and is designed especially to protect personnel using high-powered binocular and telescopes for reconnaissance or field bombardment spotting.

A new gadget, called the "sit still," that will make enough fresh water to keep survivors of sea disasters from dying of thirst, has been developed by the Army Engineer R&D Laboratories, Fort Belvoir, Va. The device uses heat from the sun's rays or from the body of an individual sitting on it to produce fresh water by condensation.

materials

Radioisotopes, x-ray, and electrical conductivity are being used to learn how lubrication affects bearing life in a research project underway at SKF Industries Inc., Front St. and Erie Av., Philadelphia 32. The study is being conducted under a $177,000 Navy Bureau of Weapons contract to improve the reliability of rolling contact bearings used in spacecraft, missiles, aircraft, warships, and atomic reactors.



COMPONENTS of the Ranger spacecraft being built by Jet Propulsion Laboratory for the NASA are shown in this close-up of a scale model.

A $34,833 contract to study the effect of surface coatings on the behavior of materials has been awarded to The Martin Co.'s Research Institute for Advanced Study, 7212 Bellona Av., Baltimore 12, by the U.S. Army Ordnance District, Philadelphia. This area of basic research has been investigated extensively by Russian scientists, but has been neglected largely by the West. One interesting application developed by the Russians has resulted in improved methods of rock-drilling.

new techniques

Development of a system using electron beams to make semiconductor devices, such as diodes, has been announced by CBS Laboratories, High Ridge Rd., Stamford, Conn. The study, under sponsorship of the U.S. Army Signal R&D Laboratories, Ft. Monmouth, N.J., demonstrated the advantages of control over small dimensions and the possibility of automated production of small, intricate structures with consequent savings in cost.

The Navy has awarded a $506,861 contract to IBM's Federal Systems Div., 326 E. Montgomery Av., Rockville, Md., to develop a high volume production system for the continuous manufacture of ultra-reliable thin film subassemblies, the potential building blocks of the next generation of electronic systems. The new system will be produced with technical guidance from the Naval Avionics Facility, Indianapolis, as part of the Bureau of Naval Weapons' industrial readiness program.

A motion picture recording technique that permits observation of the interior motions of a simulated explosion (which previously could be inferred only from external photographic records) has been developed by the Explosion Dynamics Div., U.S. Naval Ordnance Laboratory, White Oak, Md. The technique, utilizing an electronic computer, provides rapid visualization of the solutions to problems of explosion dynamics and flow. For example, a solid cylinder of explosive contained in a steel shell was mathematically detonated on the computer and its recorded sequence displayed on a motion picture screen. The detonation wave, the outward motion of the steel cylinder, and rarefaction waves sweeping back into the gas were demonstrated clearly.

Another pioneering concept in the interpretation of practical scientific advances — the RESEARCH TRENDLETTER WEEKLY— will be published as the result of a continuing, three-year demand by readers of the Trendletter section in this magazine.

If you are among I·R readers who have found the Trendletter useful, you will be interested in our plans for expansion and development of the Trendletter into a weekly service.

When publication begins this winter, the weekly Trendletter will replace the monthly section in Industrial Research. The weekly Trendletter will be similar to the section in the magazine, but in addition will:

■ Keep you appraised of your competitor's latest developments.

■ Relate news of defense and industrial contracts to their possible impact on your company and on the stock market.

■ Present applications of research in product development *weeks* before they appear in the technical press.

■ Point up trends in scientific research and technical advancement.

■ Describe what acceptance a new development is likely to have, and what project or process it might render obsolete.

■ Provide an idea file (three-ring punched) complete with source information.

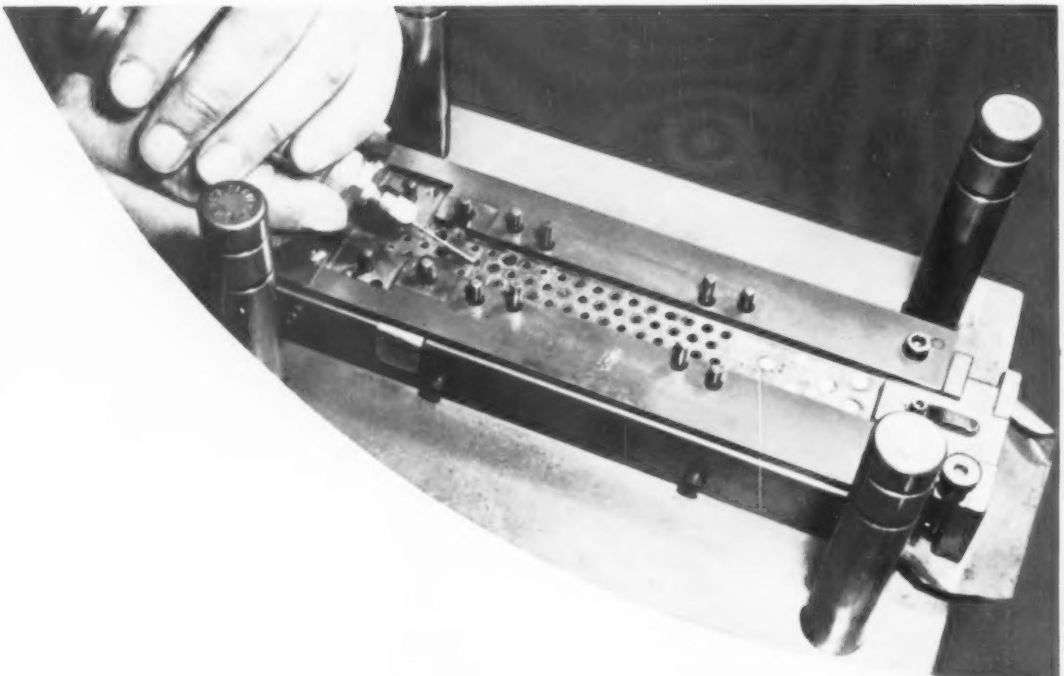
The Research Trendletter Weekly will do all these things every seven days—arriving *air mail* with Tuesday's development news

the morning of every

WE
N

Here is our Special Pre-Publication Offer: as a Charter Subscriber, you will receive the Research Trendletter Weekly at $50 annually—a savings of $25 a year over the regular price of $75. (It's tax deductable if your firm does not pay the subscription cost.) We cannot repeat this offer after publication begins.

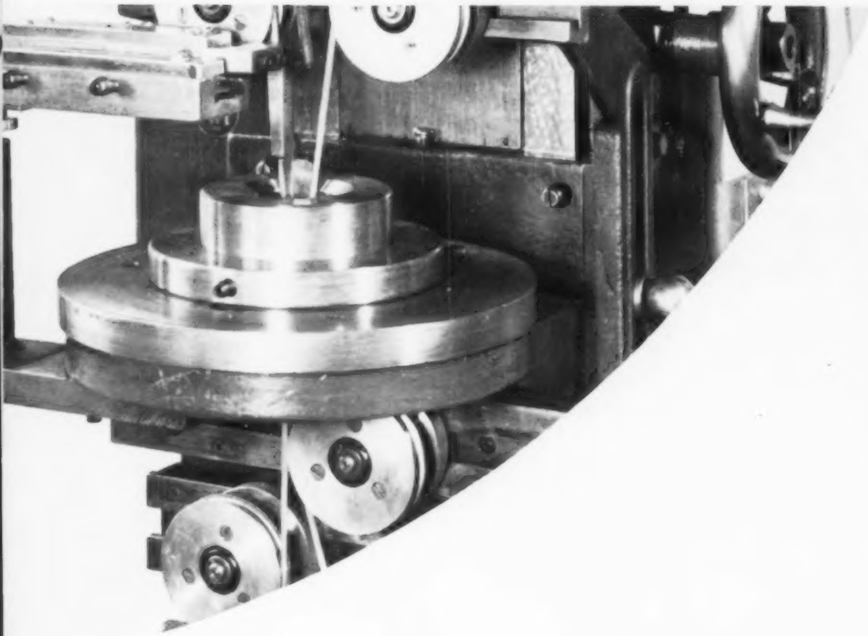
Later, next winter, after you begin receiving the Trendletter each week, if you do not find it is the most helpful service that money can buy, simply return the issues received with a note giving us your honest opinion, and we will return your full payment.



Grinding Ceramic Wafers *(below) for nuvistor tubes. Two diamond wheels finish 2000 wafers per hour for Electron Tube Division of RCA. Wheels remove 0.003" stock from each surface simultaneously. Previous method using abrasive belts ground only one surface at a time, resulting in nonuniform results and stoppages. Expected life of wheels: 5,000,000 wafers.*

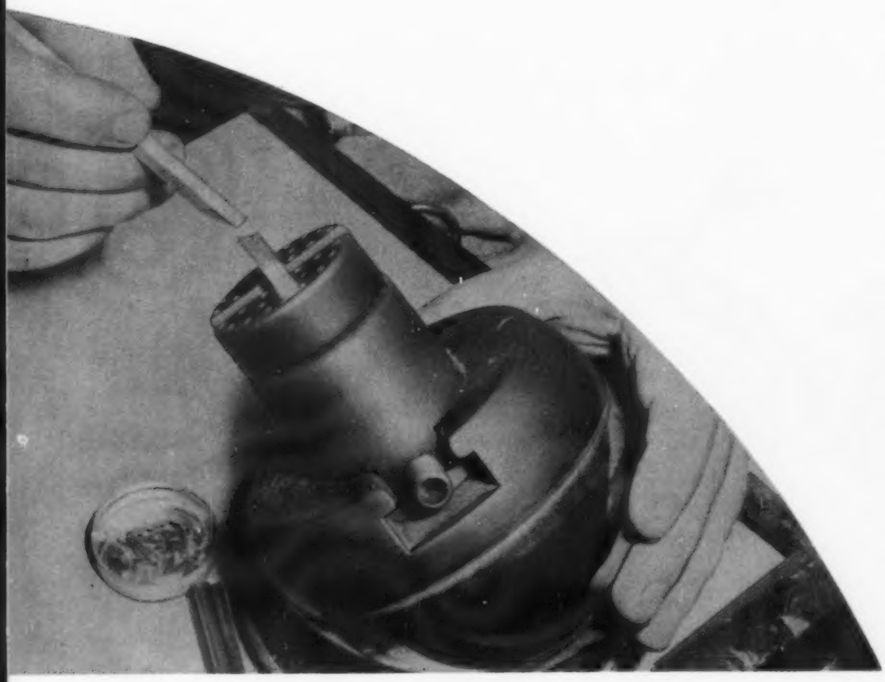
Servicing High-Speed Carbide Dies *(above). Jacoby Bender Inc. makes expansion watch bands. Their dies are for precious and semiprecious metals, as well as stainless steel. Finished products must have flawless finish. Small diamond quills from size .020" to ¼" diameter are used to build and service carbide dies. Grinders also cut decorative relief in some dies.*

Industrial diamonds cut practically everything... especially your production costs



Polishing Drawing Dies *(above)* *for Chase Brass & Copper. Die-polishing job that once required 2 to 6 hours' handwork is now finished in 15 minutes with diamond belt polisher. Accuracies and surface finishes are also greatly improved. Belts are impregnated with 100, 200 or 300 mesh natural diamond grit. Up to 200 dies have been serviced by a single belt.*

Putting Mirror Finish *(below) on hardened steel part for a forming die at Jacoby Bender. The natural diamond micron powder is applied with a wooden lap. The diamond paste speeds up the polishing operation, and has less tendency to distort the true form of the tool-steel than methods previously used.*



Considering how well natural diamonds do these jobs may give you ideas

The four grinding and polishing jobs shown here span the fields of electronics, jewelry making, and metalworking. But they have one thing in common: in every case, natural industrial diamonds are doing the job quickly, economically and well.

In diamonds, you find this unique combination of properties: excellent cutting ability coupled with fantastic endurance.

Result: your diamond tools last longer than any other tools you can use. Your people spend more time producing, less time changing tools.

If you cut, sharpen or smooth in your business, you quite probably can use natural diamonds to advantage. Test them against the method you're now using. You will see how efficient—and economical—a diamond can be, especially now.

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A new impact crushing method for natural diamonds is now producing the strongest and most durable diamond grit ever obtained for metal-bond wheels. Your tool and wheel manufacturer is ready to help you select the diamond tool that's right for *your* job.

Industrial Distributors (Sales), Ltd.

Aside from politics and perhaps the state of business, the two subjects of paramount interest today are probably research and development, and the shortage of scientists and engineers. There is scarcely a dissent raised against the importance of and need for even more research and development than we now have. And it is generally admitted that at least for some decades the number of scientists and engineers cannot have increased proportionately. According to the National Science Foundation, the cost of research and development in the United States will be of the order of $14-billion this year. To paraphrase Malthus, the supply of technical talent increases by arithmetic progression, whereas the demand has been increasing by geometric progression.

Ordinarily, when a thing is in short supply, price increases and efforts are made to use the scarce item more efficiently and economically. Nevertheless, several broad surveys made recently have shown that scientists and engineers are *used* in their professional fields only a small fraction of their time.

A failure of industrial management

This apparently uneconomic use of engineering talent is astonishing, especially in the light of additional pressures such as the cost-price squeeze, the stimulus for good professional working conditions, and the genuine desire to make technical men's work satisfying through meeting worthy professional challenges.

A primary cause of the poor utilization of engi-

the Spectrum of organizing research

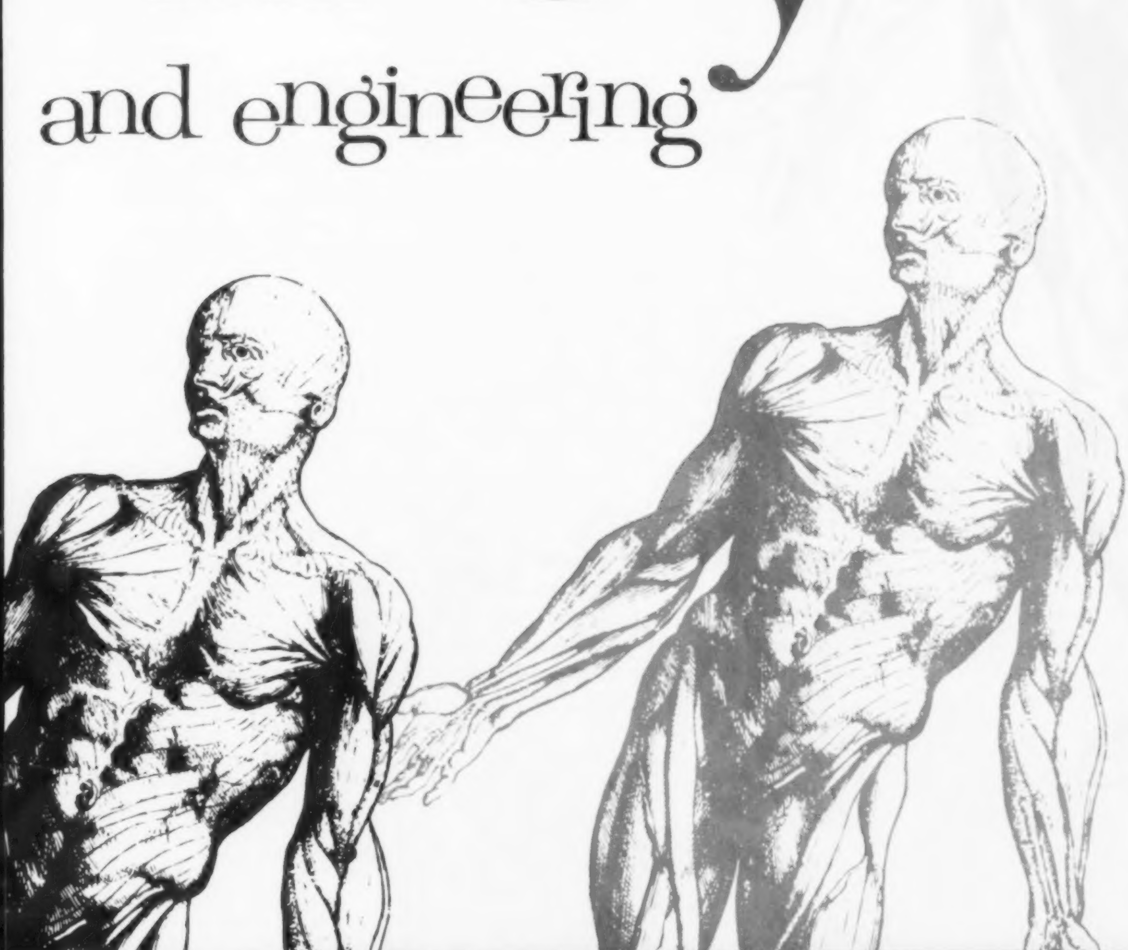
neering talent appears to be a failure of industry to devise management techniques for the optimum use of scientists and engineers. Optimum management techniques have been too confined to business administration, staff administrative procedures, and markets and sales. They have not been extended fully to include technology.

An effective vehicle for reorienting management inheres in a simple philosophy: *regard all applied science as a continuous spectrum of technology*, which it truly is. Economy of operations eventually will dictate that industrial research and development will adopt this "spectrum theory," and view applied science (technology) and all other activities of a company as an interrelated whole.

At first glance it may seem anomalous to advo-

Maj. Gen. Leslie E. Simon *(Ret.),*
staff director of research,
The Carborundum Co.,
attempts in this article to reorient technical management into regarding all applied science as a continuous spectrum of men and technology

theory and engineering



The advancing wave of technology had to await prio

cate regarding all applied science—from research to engineering on the production line—as a continuous spectrum of disciplines that can be administered advantageously by a single management. Undoubtedly, there are those among us who can remember when the single management of an engineering department administered all engineering of the company (including all scientific activities, if there happened to be any).

Stimuli to the spectrum theory

Perhaps, the same reminiscent individual also can remember the bitter struggle of those who participated early in industrial research to get out from under the dominance of the stodgy old engineering departments, so they could try their wings and really do R&D. Is the treating of all applied science as a single, closely-related and collective group advocating a return to the status quo of the "bad old days?"

The answer is no. The spectrum theory advocates returning research and engineering to a single organization (together with several other things), but in no sense returning to the antagonisms of the bad old days. In fact, some industries already have returned to an even closer working relation between research and engineering than ever has existed before. What was ill for research two decades ago may be indispensable to the efficiency of both research and engineering in today's increasingly fast-paced technology, where you even find companies with more technical workers than production workers.

In the interest of proper perspective, let us examine briefly three periods that can be classified roughly as pre-World War II, the decade of 1941-50, and post-1950. Because we cannot look too far into the future (and for purposes of argument, it makes no difference), let us call the third period 1950-70.

Machine age and invention

In the period prior to WW II we had highly mechanized production, engineering associated with design and production, and invention, but very little industrial research worth the name. New things came from inventors who, by and large, happened to stumble upon a new thing in much the same way that the gold prospector of '49 stumbled upon a gold nugget.

The engineering departments were very practical, which is another way of saying highly empirical.

recognition of the advantages of scientific R&D administration.

They had to be, or somebody would get fired. They would accept an invention, if its value were demonstrated effectively and if it were conspicuously giltedged. But inventors were regarded as a queer and unreliable lot. Actually they were marked variants, for the orderly process of basic research, engineering research, development, pilot-lining, manufacturing, and marketing was yet to be discovered.

If the lone inventor's achievement of a successful new product is comparable to the lone prospector's finding of a nugget, we had yet to learn a lesson from the successful gold mining companies who get more than 95% of their gold from the orderly process of refining gold dust, not from nuggets. There was little acceptance of scientists except in the universities. And although the colleges graduated few scientists and engineers as compared with the current output, they were not in great demand and were relatively low paid.

As late as the third decade of the twentieth century, Dr. Thornton C. Fry, of Bell Telephone Laboratories, stated publicly that he believed himself to be the *only* full-time mathematician employed for industrial work! There was no need to take special measures to employ the engineer for a maximum of time at his highest skill; if his usefulness was not promptly and patently apparent, he was fired and another employed.

Contrast the pre-WW II demand for technology with today's. The federal government now spends of the order of $9-billion on R&D annually, whereas it spent only about a thousandth of that per year before WW II.

However, let us note that slowness in the efficient use of technology does not necessarily imply universal intellectual slowness. By way of contrast, the early part of the 20th century saw great advances in shop management, such as the Taylor System, and marked advances in scientific business administration, such as the methods taught by the Harvard Business School.

The economic advantages of scientific business administration were recognized, whereas the advantages of scientific administration of research and engineering were not. R&D was still too young and too little understood. Even the great leverage power of engineering was not yet fully realized and there was little incentive for the economic utilization of engineers, when engineers (except for those who became managers) were cheap and not in short supply.

The scientific decade (1941-50)

WW II focused attention on science and engineering. Destructive as wars are of life and property, some serendipitous benefits generally result. The Spanish-American War stimulated the birth of the National Academy of Sciences. WW I ushered in the National Research Council. WW II brought the birth of the National Defense Research Council (NDRC), which was succeeded by the Office of Scientific Research & Development (OSRD), both under Dr. Vannevar Bush. WW II also brought great military research and development activity by the few old and many new laboratories of all belligerent governments to improve armaments.

Among conspicuous results were radar, the A-bomb, jet aircraft, electronic digital computing, and widespread practical use of statistical methods, to mention only a few. Without the stimulus of WW II, both the scientific age and the automated and highly technological times in which we now live might have been delayed much longer.

[*Editor's note: Two diametrically opposed conjectures have been made with respect to the effect of WW II upon science. One side argues that the enormous stimulation of giant projects like the atom bomb helped science. The other says that the mobilization of men and money for war was a diversion away from science. An interesting idea, discussed in the new book* Science Since Babylon *(Yale University Press, 1961) by Yale's Derek J. de Solla Price, holds that neither of these things happened—or if they did, they balanced each other so effectively that no resultant effect can be found.*]

The end products of R&D had wide popular appeal, although the rather unplanned method by which they came about was understood incompletely. Research and development became very popular, scientists became respectable, and scientists and engineers were in demand.

Yet during the postwar lull (1946-50), not very much was done about the shortage of engineers, other than more and more "help wanted" advertisements in the Sunday New York Times. Research and development had not yet experienced the exponential expansion of the 1950s and the demands for economy of operations associated with the price-wage squeeze were not acute. Whereas there was some thinking about the supply of and the effective use of engineers, as demonstrated by our concern about education, the general attitude was rather one of sitting back and waiting, letting the situa-

Maximum use of engineering talent is possible . . . but first

tion by itself develop to a state of greater clarity.

Unless you are associated with some of our industries on the forefront of the advancing wave of technology, such as missiles, aircraft, and electronics, it is difficult to comprehend and accept the acceleration and ever-increasing magnitude of changes going on around us.

Our current age of technology

Less than a decade ago, we talked boldly of "telescoping" on high-priority projects, when we ventured to begin the manufacture of engineering test models before component tests were completed. Today, production lines are started before enough of the components have been proved out to have full tests of sub-systems.

In some industries, not only have the dividing lines between research and engineering all but disappeared, but there is no pause in the transition from engineering to manufacture. The same kinds of people, if not the same people, are exercising control throughout. Organizational and managerial steps that we take under the pressure of expediency surely should prompt us to consider how we can take similar steps to improve our economy of time and effort on a deliberately planned basis.

Concurrent with the compression of time, four important changes must be noted—allocation of costs, allocation of people, speed of obsolescence, and new technologies used:

- So-called "engineering costs" often exceed the cost of production, not only in missiles but sometimes in jet aircraft.
- In many companies, technical personnel are almost as great or greater in number than production personnel.
- Advances in miniaturization are so swift that miniature electronic designs do not get into real production before they are succeeded by microminiature designs.
- Statistical methods such as "reliability" now permeate industry. [*Editor's note: The author coined the word "reliability" to cover a hybrid system of statistical quality control, engineering, and management. The system was devised by the author and others in Army Ordnance as a necessity to getting the NIKE missile operational.*] The "PERT" system, born in 1958 of a Navy project as a statistical approach to planning, scheduling, review, and evaluation already is used widely with variations in the aerospace industries.

Whereas the shortage of engineers is now well recognized, the remedial measure most discussed—larger enrollment of engineering students—is almost certain to be inadequate and slow. In fact, there are strong reasons for believing that, despite best efforts, the shortage of technological talent is here to stay for a long time to come.

The intensification of scientific and engineering education is fine, but the increase in scientists and engineers is not going to be proportional to the increased college enrollment. Any large increase in quantity of engineering students is almost sure to involve some decrease in quality, when we already are trying to educate too many young people who simply are not college material. The graduation of unqualified persons is tacitly recognized by industry's demand for persons in the upper third or upper half of the class.

However, it should be noted that those who do not have real professional ability could be utilized to excellent advantage as sub-professional technicians—if only their work were dignified by status, title, and emoluments, and if only we would arrange the spectrum of our technical work so as to utilize them effectively and give them opportunity for pride in their work.

Aside from the long-term viewpoint, relief from the shortage of technical talent is needed before educational programs can bear fruit. If and when the supply is increased, the demand will be increased even more because of forces already in operation. For example, the wage-price squeeze and the foreign competition squeeze call for more automation as an alternative to reduction of our standard of living, thereby adding a positive second

A specialist in research management, statistical quality control, and development of missiles, aircraft, and ground weapons, Gen. Leslie E. Simon has had distinguished careers both in industry and in the military. He joined The Carborundum Co. as vice-president and director of the Research & Development Div. in 1955, and was responsible for reorganizing the company's R&D activities and expanding personnel and facilities of the Central Research Laboratory to its present capacity. He also was instrumental in organizing technical branches for the operating divisions, and greatly increased emphasis on technical development throughout the company. As staff director of research, he is acting in a consulting capacity to the president of the company. Gen. Simon is the recipient of the Distinguished Service Medal for military R&D.

a company must know itself in all its fundamental aspects.

derivative to the already upward curve of demand for technology.

Prerequisite to spectrum operation

Knowing oneself is often prescribed to a young person as a prerequisite to planning a career. A company, no less than an individual, first should know itself in all of its fundamental aspects—its physical, intellectual, and intangible assets and liabilities—before planning a serious organizational step. Like a rational individual, a company, should outline its objectives and its policies and procedures for achieving them. It is then ready to define optimum managerial procedures and a most effective organization.

How then may we go about rearranging a company so as to maximize use of the engineer, and incidentally increase the use of the sub-professional technicians? Fortunately, the answers to many serious problems are simple, at least in principle. Here is one possible procedure:

- **Step 1: inventory of technical functions.** Examine everything which has a reasonable bearing on technology that the company or each division of the company does (not how it does it). It is important that this examination be done, not by enumerating the operations actually performed, but by classifying each operation in its general functional category, while at the same time relating it to the type of knowledge required to perform the function.

You would not record "Test coils of wire received for tensile strength." Instead, you would have such *functional categories* and sub-categories as (1) raw materials, (a) inorganic components, (a-1) minerals. You also would have a parallel list of

categories of *type of knowledge required*, for example (1) bulk properties, (a) physical composition, etc. Thus, the testing of coils of wire received for tensile strength would be recorded as "minerals —bulk properties," and this would be a *technical function*.

In discussing disciplines in step 2 below, we shall see that this technical function, if highly repetitive, would be associated with a sub-professional technician. But if it pertained to many kinds of wire and required judgment, you would associate it with a mechanical engineer. Finally, you might make it (but grudgingly) a minor additional duty of almost any engineer or physicist, provided the function occurred only infrequently.

Unless this classification of the observed function by technical relation is observed faithfully, the inventory will tend to be a mere enumeration of product operations. Instead, it should be an enumeration of abstract technical functions that provide a common denominator for a transition from what one does to the kinds of disciplines one should exercise in doing it. Various systematic approaches can be devised for simplifying the inventory procedure and insuring that the end result will be in terms of categories of functions that can be related to the exercise of disciplines.

- **Step 2: identification of disciplines.** Each technical function (a functional category plus a category of type knowledge) will require for its execution the exercise of knowledge that is derived from a discipline. Identify each of the technical functions with disciplines; that is, skills or abilities ordinarily taught in universites or acquired in normal work experience to the extent of achieving both a skill and a basic understanding thereof. Do not include work experience peculiar to a company or product, nor work experience in which the operator merely is exposed as a witness to the discipline.

Note that a major work operation in a company may require, and usually does require, the exercise of several disciplines, and that a specific discipline will occur again and again relative to various technical functions.

The identification of disciplines may sound easier than it is. Actually the procedure of classifying operations performed under functional categories plus types of knowledge, and then relating the *technical functions* thus derived to disciplines, must be repeated several times. For example, the procedure must be repeated once for *scientific know-*

ledge, once for *statistical methodology*, and once for *engineering design and standards*. Some such reiterative process is necessary because you cannot operate in "n" dimensional space while confined to the plane of a piece of paper.

However, the tedium is well rewarded because *the complete procedure identifies the interactions between "functions"* (our categorical expression of operations); *"types of knowledge required"* (thereby yielding technical functions); and *"disciplines."* These are matters that merely may be sensed, at best, rather than clearly understood, even when important men are hired to do specific jobs.

This is a highly abridged presentation of the procedure for inventory of technical functions and identification of the disciplines. It is given, not to be useful in doing such an analysis, but to throw light on why and how treating all technology as a continuum of applied science affects an economy in scarce technical personnel. The two steps—inventory of technical functions and identification of disciplines—will accomplish several things:

- Identify the nature and extent to which applied science is required in all operations of a company.
- Define the nature of each respective requirement.
- Provide a basis for determining approximately how many technical people really are needed.

Minimum requirements for technical men

At this point we know in an ideal sense what disciplines are required in the company. From the number of times that each discipline is required, we can assess, at least relatively, the amount or volume of the requirement for each discipline.

After selecting one or more disciplines as a base, and finding out through trial-and-error techniques how many persons are required in the base discipline, we can estimate approximately the minimum number of persons required to do all the company technical functions. This, of course, assumes using a person in his discipline of highest skill a majority of the time.

With a comprehensive knowledge of the quantity and kind of applied science required by the company and the nature of each requirement readily available, you now can set about designing an organization for maximizing the use of the scientist or engineer. Subsequently, various practical considerations will require modifications of the organization. These will tend to degrade the maximum use of the engineer, but his employment still will be relatively efficient.

Technical functions and disciplines should be studied objectively and jobs or positions should be made from a concentration of technical functions that are dependent on the knowledge associated with a discipline or a knowledge of a minimum of disciplines.

With these points in view, the manager thoroughly conversant with a company can readily outline a chart that will show how technology should flow from groups of disciplines to other groups of like or different groups of disciplines throughout a company. The Carborundum Co., for example, could be charted as shown on page 60. Another type of company would take a different chart.

In addition to being consistent with disciplinary integrity, the chart should provide:

- An orderly and efficient horizontal flow of each kind of technology from division to division that extends from the disciplinary group of highest level of ability (staff) to the echelon that requires only the lowest competence (manufacturing).
- A clear channel of communication vertically through the different disciplinary groups, or sections within each major division.

This type of chart has nothing to do with people. In fact, it is best to regard the smallest sub-groups shown (sub-sections in the illustration) as *technical elements*. In a flow chart of technology, such as the one for Carborundum, there may be some operating divisions in which one or more technical elements will consist of only one man. Sometimes a man will supply two or more technical elements.

In some operating divisions, it may not be economical for the operating division to maintain the technical element. Instead, it may be more economical to obtain the required technology as a service from another operating division or from the research and engineering division.

Smallness of demand for a certain type of technology does not imply absence of the technical element, or that it should be neglected, or that an engineer should be hired who would be utilized poorly. It means only that the economical supply of that type of technology is an organizational problem (for which there should be several reasonably good solutions), and that steps one and two have done a valuable service in bringing the condition to light.

Manpower for spectrum operation

Nothing is more important to research and engineering than people. Yet, if you are going to design and man an organization so as to achieve the advantages of treating all applied science as a continuum, it is best that you blank out, at least temporarily, the intuitive way of viewing a company as a network of individuals each responsible for an area of products or an area of business. Instead, you should view the company, insofar as technology is concerned, as a complex of requirements for *packages of applied science* (one or more technical elements), where the package must admit of being supplied by a person who is competent in a discipline.

Thus, the organizer tries to end up with a group of persons each of whom primarily exercises the discipline of his special competence, but arranged by virtue of communication and position so as to be able to act readily in these ways:

- Each person should be able to join easily with colleagues of other disciplines for the solution of today's problems, the majority of which are solved best through the mingling of and interaction between diverse disciplines (the antithesis of the compartmentization imposed by many organizations).
- Insofar as practicable, each person representing a certain degree of competence in a discipline should be able to have ready access to a person of higher competence in his discipline for assistance on phases of problems that may be beyond his capability. Similarly, he should be able to pass the problem down to someone lower in the hierarchy of his discipline, if the problem, or significant phases of it, does not require his degree of competence.

With this viewpoint in mind, let us return to the output of steps one and two. These two steps have analyzed the amount and kinds of disciplines that must be exercised to do all the work of the company. But except for the guidance of the flow chart of technology, there has been no inference of order or arrangement with regard to the component parts of the company's technology.

Note that the technical functions probably were not jobs in the old organization, and only rarely should a technical function happen to be a job in any new one. In short, all of the pieces of the puzzle are present. The task is one of assembling them in an optimum manner. One possible procedure is:

- Examine the frequency of occurrence of each discipline—for example, inorganic chemist—and relate the level of knowledge required to the several technical functions that caused the recording of the discipline.
- Observe what technical functions that relate to a single discipline (or at worst, a very few closely related disciplines) admit of being collected together as a rational sub-group, where the technical functions require, insofar as practicable, about the same degree of expertness in the discipline.

Later revisions and alterations of one's work will be minimized if care is taken to avoid obvious anomalies such as having a single exerciser of a discipline in two widely separated locations. These collections automatically become jobs for one person, if the implied work is consistent with what should be expected of a man, or for a number of like jobs, if the magnitude of the collection is great.

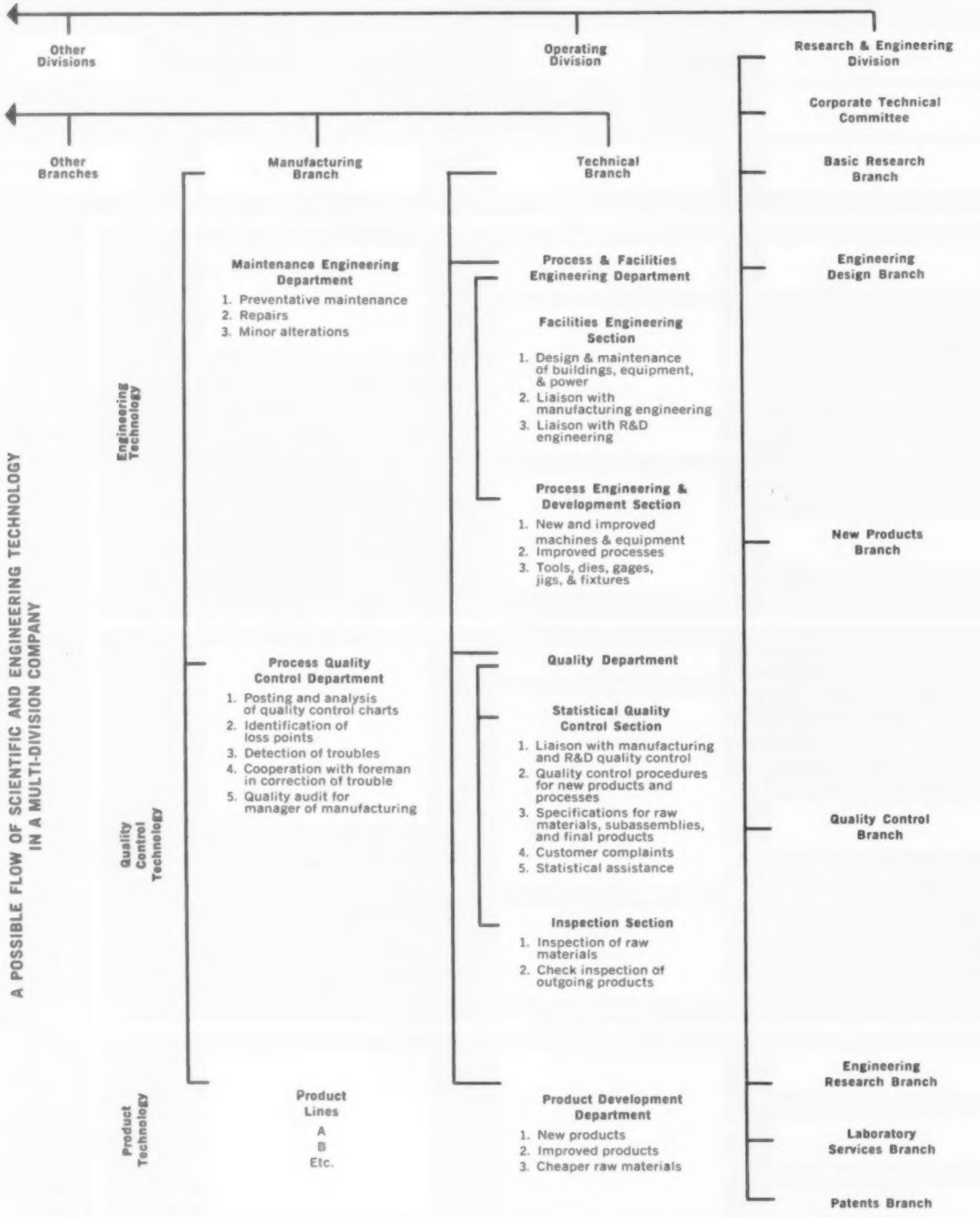
If the data is valid and the collections rational, the created jobs *ipso facto* must utilize the incumbent for a maximum of time in his primary discipline.

- Make a tentative organization consistent with the flow chart, and arrange the corresponding jobs in such a way that the incumbent has clear channels of communication. This should be done laterally, so the employe can lend support to his colleagues when they have need for his specialty, and vertically, so that the incumbent can apply for help to a superior on problems that exceed his competence and delegate work to those beneath him on problems that do not require his competency.

In practice, this procedure requires a mass of detail too voluminous to be given here, as well as some practical concessions in the interest of preserving the usefulness of some currently available persons. Furthermore, a plan should provide flexibility for change or expansion to meet changing or probable future conditions. The thesis is that the spectrum system is good—not that it is easy to design and install.

However, one more matter should be presented that is important and easy, if the preceding analyses have been made.

Most companies have job sheets or position descriptions for at least their more important jobs. What they often do not have, and what is equally if not more important, is a clear delineation of requirements for each job. The job requirements should constitute a clear description of the kinds of knowledge and skills required and should define the formal training (education), informal training (relevant work experience), and other abilities that the



A POSSIBLE FLOW OF SCIENTIFIC AND ENGINEERING TECHNOLOGY IN A MULTI-DIVISION COMPANY

prospective incumbent of the job should have. For each item under *responsibilities* in the position description, there should be an enumeration of *requisite training* in the job requirements.

If care relative to job requirements seems unimportant, let me ask how often you have written a job around a man? If you are guilty, it is proof that a subjective choice was made, instead of one based on a scientific analysis of the real requirements of the company.

A continuous spectrum of technology results in a saving of personnel . . .

If the process of making job descriptions matched against job requirements seems onerous, let us observe some of the rewards.

The job requirements' sheet is the test of the validity of the job description. It often is found that the better and more precisely a job description is expressed, the more nearly it is to impossible for the personnel manager to fill the job. *The cause is not the careful delineation of the job*, but the fact that a job has been selected and described that requires for its execution the possession of more kinds of knowledge and skills than a person ordinarily possesses.

In these days of mobile and restless labor of all sorts, jobs simply must bear a relatively close correspondence to disciplines taught in colleges or acquired through normal work training. Hence, a statement of job requirements is an indispensable test of whether the rational sub-groups of technical functions, which became jobs, were really *rational*. If the formulation of requirements gives difficulty, you should review the job for rationality.

It is relatively easy to devise a system of dividing the respective requirements into those for which formal training is highly desirable and those for which informal training is acceptable. You then can assign relative weights to the respective elements so as to yield a numerical score for each prospective candidate for a job. Although the numerical score may not always be definitive, especially when there is not a large difference between numerical scores, it is an excellent guide to judgment.

The information for evaluating the merit of company employes for newly created jobs, or vacancies for old jobs, can be obtained almost in its entirety from personnel department records. This is particularly important if a reorganization is taking place, both from the viewpoint of preserving the services of old employes and from the viewpoint of filling those new positions that cannot be filled from within the company.

If the above procedure is used, it is astonishing how much valuable, and perhaps only partially used, talent you can turn up in your own organization. Often you find that the kind of man urgently needed for an important new position in one division of a company is occupying a relatively low position, where he is used in poor degree, in another division. Companies have a great deal of talent hidden on their own premises. Too often, the more articulate person, rather than the more meritorious, is the one selected for advancement within the company.

Some advantages of spectrum operation

The observation on position requirements points to a marked advantage of spectrum operation to an individual and to a company. In actual practice, it was found that some divisions of a company that were trying hard to hire new engineers turned out to have enough, if not too many, of them. They were just not using them to full advantage.

Some divisions had men who could be promoted in quite substantial degree by transfer to other divisions. In fact, almost all men benefited, except for a few old employes whose principal value was long work experience in matters peculiar to the company; useful places involving no demotion could be found for most of these, with little or no loss to the company through over-payment.

Spectrum operation also provides a stimulus to professional and sub-professional staff members to improve themselves for advancement. Thus, having a continuous spectrum of technology results in a saving in personnel. It results also in a greater ability to use sub-professional technicians instead of professional people.

Bridging research and production

The continuum helps bridge the discontinuity between research and development. The even worse gap between development and production (which is due largely to engineering's being separate) practically disappears. Orientation of the technical structure can be made to correspond more clearly to company objectives, and technology becomes geared to customer need and markets through the broadened outlook obtained from increased participation in tasks that use diverse disciplines.

The technical people are of greater value to the company and most of them thereby become better paid. The scientist or engineer is less constrained to do tasks that do not require his skill. He accomplishes more and enjoys his work more, thereby enhancing employe satisfaction. His work with multi-discipline groups broadens his outlook and his exchanges of information through lateral and vertical communication give him wider interests. Hence, he is both a more useful and a happier man.

Finally, any measure that better utilizes technical talent is good for the nation. For, unless we achieve scientific and technical efficiency, we cannot continue to compete successfully in world markets. ■

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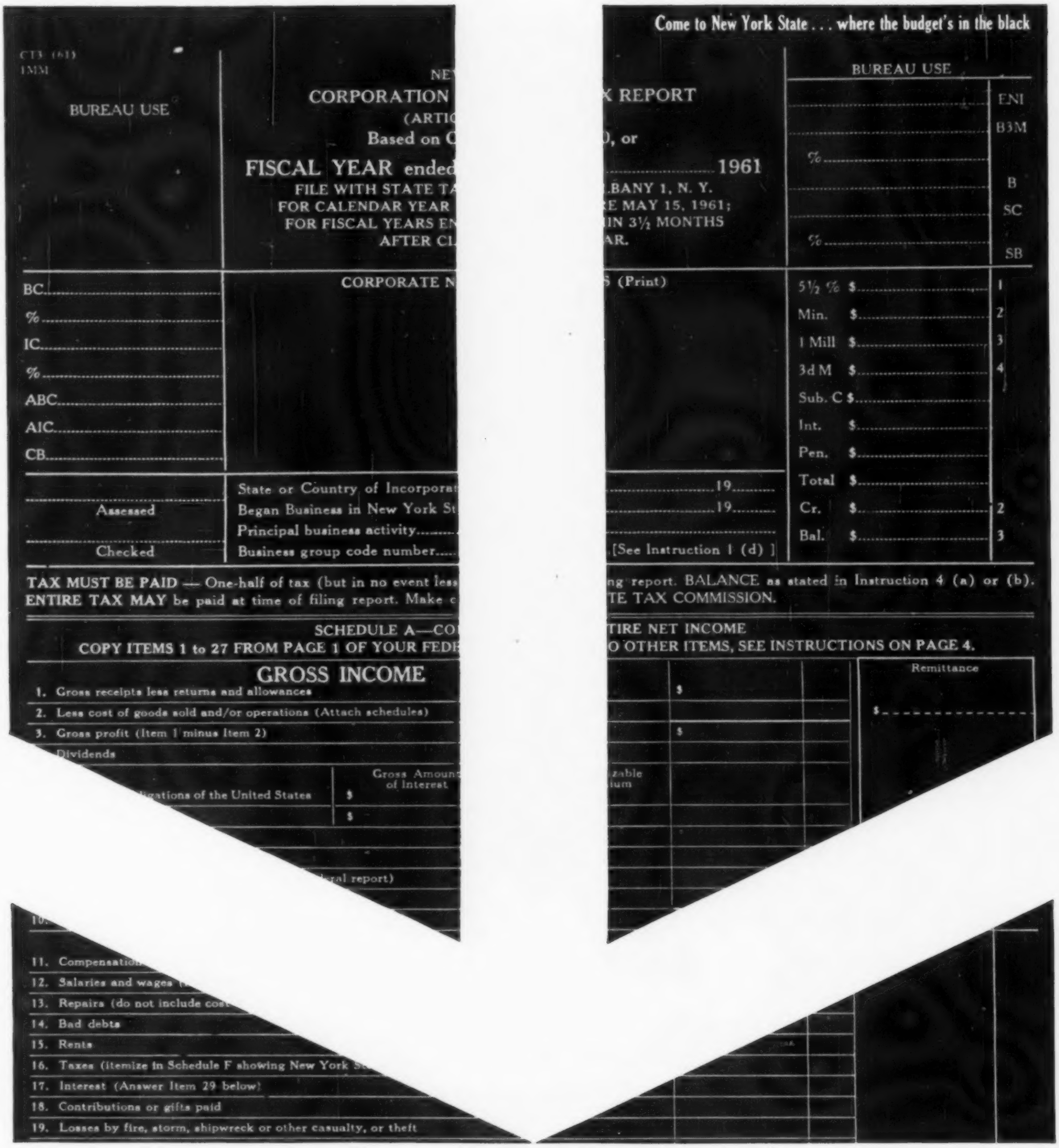
☐ A PLACE IN THE SUN is offered for your ideas in a receptive environment that permits an idea to achieve its fullest potential. For more information on employment opportunities, write to: Fairchild Semiconductor Div., Fairchild Camera & Instrument Corp., 545 Whisman Rd., Mountain View, Calif.

(For more employment opportunities, see page 66.)



TAXES LOWER IN NEW YORK THAN IN 21 OTHER STATES

If you've been told that New York is a high-tax state, and are, perhaps, hesitating to set up a new plant here, you're in for a surprise right now. The tax bill for industry in New York is less than that of many industrial states. In fact, almost half of the states in the entire country have a higher tax rate per dollar of personal income than New York State. Yet New York has been able to finance one of the nation's most extensive highway, education and public-works programs while reducing taxes in 1961. Other factors, too, explain why New York businessmen are investing in expansion at the rate of $150 million a month. The State budget is in sound fiscal condition. What's more, New York State provides business with the nation's number-one market: 17 million people who earn $48 billion a year, spend $23 billion at retail and have $67 billion in the bank. All of which helps document the fact that New York State's climate for profit and progress is second to none in the nation. *We will prepare for you*—without cost or obligation—a confidential survey of proposed plant sites in New York State, selected to fit your needs. Outline your requirements on your business letterhead and send them to Commissioner Keith S. McHugh, Department of Commerce, Room 3904, 112 State Street, Albany 7, N. Y.

N.Y.S.

RESEARCH COMMENT

Dr. A. O. Beckman, president, Beckman Instruments Inc., before Western Electronic Mfgrs. Assn., San Francisco:

"I see evidence in some quarters of a 'second place-manship' philosophy which flatly contradicts the pioneering spirit proclaimed for the electronics industry. This philosophy is translated into a business strategy that leaves the pioneering leadership to others with the aim of grabbing business through the quick production of a cheaper version of the pioneer's product. I think this is an exceedingly dangerous note in an industry which has based so much of its success on basic innovation."

Henry W. Harding, president, Laboratory for Electronics Inc., before N.Y. Security Analysts Society:

"More than one-third of the electronics firms presently in existence may be out of business by 1975, as a result of a generally decreasing growth rate in the electronics industry during the next few years.

"At this lower growth rate, the industry is going to find it increasingly difficult to absorb and justify the extremely high cost of research and development and engineering of prototypes. If one adds to this the effects of changes in market 'shares'—military vs. industrial vs. consumer, and replacement—one can see what is about to happen: an exacting toll in the form of sharply increased business mortality rates."

Sen. Hubert H. Humphrey (D. Minn.), appeal for basic research funds before the Senate:

"It is an unfortunate fact, in my judgment, that the full amounts requested in the budget presentation by the Department of Defense for basic research were not approved by our Senate committee or by the House Committee on Appropriations. Not only should the full amounts have been approved, but larger sums should have been requested for the next fiscal year.

"Basic research provides the indispensible foundation for expanding knowledge for the revolutionary weapons systems of tomorrow. There is not a single major advanced weapons system today—whether it is nuclear weaponary, guided missiles, or any other weapons — which would have been possible without basic research.

"In addition, the byproducts from basic research, as supported by the Department of Defense, tend to repay themselves manyfold in terms of eventual civilian-type advances, useful to our entire population."

Brig. Gen. David Sarnoff, chairman, Radio Corporation of America, before the National Press Club, Washington:

"The much-debated question of satellite ownership is, in my opinion, far less important at this time than the adoption of the right system at the earliest possible moment. I believe that if we coordinate our knowledge and our skills, formulate a definite plan and concentrate on our objectives, we can be the first nation to establish and operate a global system of satellite communications. This would be a dramatic advance in the use of outer space for peaceful purposes. It would benefit all mankind and give an effective demonstration of American initiative, vigor, and leadership."

Bay E. Estes Jr., vice-president, U.S. Steel Corp., before the Industrial Designers Institute, Chicago:

"In our country, cult of growth for growth's sake, parading as progress, but looking very much like the statism that other lands have accepted, is loudly proclaiming its supposed superiority over our traditions of individual dignity and liberty.

"We speak of 'the economy' as if it were a machine and we chart its 'growth' in dollars of 'gross national product,' which are as fictional in meaning as they are diluted in real value by inflation. We ignore the reality that the economy is not products —it is people—and economics is not statistics but rather the material manifestation of human action and the satisfactions underlying freedom of choice."

Philip Sporn, president, American Electric Power Co., energizing ceremony, Apple Grove Project, W. Va.:

"Looking ahead to the year 2000, electric energy generation, which last year amounted to close to 750-billion kwh, will by the year 2000 equal 6-trillion kwh, an eightfold growth in the 40-year period. The capacity to

supply this energy obviously will have to grow almost as much. Compared with 175-million kw of installed capacity in the industry in 1960, the year 2000 will see an installed capacity of 1,250-million kw.

"This vast increase in the scale of electric energy production will be accompanied by major changes in the scale of electric generating facilities. We are rather quickly and quietly coming into an era of a million kwh in a single generating unit. With this, the era of 1,000 megawatts at a single plant location has come, and had hardly the time to take a bow, when it was pushed out of the way to make room for the 2,000-, 2,500-, or 3,000-mw plant at a single location. Such plants are well on the way."

Dr. L. M. White, research director, U.S. Rubber Co., before a group of college teachers, Rochester, N.Y.:

"Many critics of our educational system are unduly preoccupied with those few brilliant students, the less than 5%. Equal concern should be felt for the 95% of our young people who will build and operate our automatic machines, grow crops for our expanding population, run for our highest offices, fill the increasing number of teaching vacancies in our classrooms, and, we hope, vote intelligently.

"Train in breadth the mass of the people and we will have better managed companies, more conscientious unions, an informed electorate, and a nation anxious to preserve its freedoms. Concentrate on the few and possibly the few will take over the thinking function."

T. A. Smith, executive vice-president, RCA, before the Army Management School, Ft. Belvoir, Va.:

"American business must match the information-handling efficiencies of its electronic systems with equivalent advances in the art of human communications if it is to achieve its long-range goals. The computer age is populated by a 1960 model human being much like the 1950 version, with an appetite for information far stronger than that of the most voracious business machine."

John J. Burns, president, RCA, in commencement address at California Institute of Technology, Pasadena:

"Bionics aims at studying living creatures, such as birds, in the hope of indicating by electronic techniques their marvelous mechanisms of communications and control. I am just waiting for some television comedian to say, 'Electronics is for the birds.' He probably will never know what a profound statement he made.**"**

IR

EMPLOYMENT CLEARINGHOUSE

Positions wanted

DIRECTOR OF ENGINEERING—BSME, graduate study and 19 years of professional experience. Intensive background in creative and administrative engineering areas for the past 10 years. Broad technical coverage in mechanical, plastic, rocket, and ballistic systems and components for aerospace. Ability to sell ideas in reports and direct presentation. Knowledgeable in sales, costing, manufacturing, and quality control.

Box 202, Industrial Research, Beverly Shores, Ind.

EXECUTIVE ASSISTANT TO PRESIDENT—Are you looking for someone to lighten your work load, with skill and imagination? I can take charge of the administrative details of your office, provide coordination and follow-up in the implementation of plans and programs . . . or oversee the formulation and execution of advertising and promotion plans and programs. I am now the director of advertising with one of America's top corporations, primarily involved in nucleonics, electronics, aerospace, etc. College degree, under 40, married, veteran, non-reservist, have "secret" clearance.

Box 205, Industrial Research, Beverly Shores, Ind.

RESEARCH DIRECTOR of medium-size electrical manufacturing company finds advancement blocked by nepotism. Has solid engineering background in electrical, mechanical, optical, and management areas. Proven history as an "idea" man. Age 45, BSEE, currently at $25,000 plus. Prefer midwest location, but might consider California.

, Box 206, Industrial Research, Beverly Shores, Ind.

ENGINEER ENTREPRENEUR — Technical innovator with experience in foreseeing market potential in technical developments. Appreciation of economic value backed by scientific training plus extensive engineering experience. Outlook is international in scope. Skilled as a team builder; emphasizes goal-orientation and technical feasibility. Best contribution would derive from strong experience in liaison, contact, and coordination gained from current employment in development laboratory of leading U.S. manufacturer.

Box 207, Industrial Research, Beverly Shores, Ind.

Positions open

MANAGER OF RESEARCH —Advanced degree in sanitary or chemical engineering with 10 years' experience in water and waste treatment or related field. To direct R&D program of nationally known, progressive company. Will select own staff (ultimately 15 to 20). A man of recognized professional standing and administrative ability is required, to originate and apply new methods and procedures to the development of new processes and equipment designs.

Send resumé and salary requirements to Mr. S. Lenox, The Permutit Co., 50 W. 44th St., New York 36.

MANAGEMENT-ORIENTED DESIGN/ENGINEERS — Challenging, responsible positions in expanding product development firm open to self-starting creative engineers. Require men capable of active design work with the ability to communicate with top management. Optional stock purchase plan.

Norland Associates Inc., Fort Atkinson, Wisc.

CLASSIFIED RATES for this section are 50 cents per word, minimum 50 words. Count box numbers as six words. Closing date for both position-wanted and position-open classified ads to appear in the next, December, issue is Nov. 8. Checks must accompany insertions.

(Display ads also may be positioned in this section at regular display rates. For a rate and data card, write the Advertising Dept., Industrial Research, Beverly Shores, Ind., or call any of our sales offices listed on page 68.) ■

A MESSAGE DIRECTED TO ENGINEERS AND SCIENTISTS WHO HAVE RECEIVED THEIR DOCTORAL DEGREES AND ARE RECOGNIZED AUTHORITIES IN THEIR FIELDS

KEARFOTT ANNOUNCES THE ESTABLISHMENT OF A NEW RESEARCH CENTER FOR THE AEROSPACE SCIENCES

under the direction of Dr. Robert C. Langford

Dr. R. C. Langford, Director of the new Kearfott Research Center, has joined Kearfott after 18 years as R&D Director in a major electronics corporation. He was graduated with a Doctorate as a Swan Research Fellow from the University of London. He is senior member of IRE, a founder member of the American Nuclear Society and a member of the American Rocket Society. An author of technical articles and lecturer, he has also been a member of a U.S. Government committee analyzing Russian accomplishments in the electronic and solid state fields.

To meet accelerating national goals in space, upper atmosphere flight and undersea defense, radical advances in many technologies are essential. Kearfott, long a leader* in the development of systems and components for control, navigation and guidance, is preparing to enhance its endeavor in these and allied areas, through a multidisciplinary program of Applied Research. To this end, the new Research Center has been established. It will complement but not duplicate discrete R&D activities of the 26 Kearfott laboratories now functioning within the company's 8 Engineering Divisions.

*20 Kearfott precision instrument devices played a part in recent successful space flights of America's astronauts.

Dr. Langford Details Kearfott Philosophy of New Center

"This will be a scientific community entirely concerned with scientific and technical investigations; totally divorced from administrative or development responsibilities.

"Principal Staff Scientists will report to the Director—without any intervening 'level-of-command' to obscure a research man's ideas."

THE CENTER'S METHOD OF PROBLEM-SEEKING "Study areas will be related as closely as possible to urgent government needs. Senior members of the staff will seek, in conjunction with government scientists and other personnel, to determine the most difficult problems requiring solution (particularly but not exclusively, in control, navigation and guidance areas). It will then be up to the Center scientists to formulate appropriate investigations."

RESEARCH RESPONSIBILITY "The individual will guide his own research, calling upon Center resources for any technical assistance he requires. (Successful concepts will be carried to the prototype stage by Kearfott's engineering organization, without close supervision by the scientist, who may turn to other problems)."

CONSULTANTS IN LEADING INSTITUTIONS "Arrangements have been made for consultation with outstanding authorities at universities and foundations in this country and abroad. A stimulating cross-fertilization of ideas is projected, both with colleagues here and outside the Center."

SERVE ON DOD COMMITTEES "In the national interest, Center scientists will themselves feel free to act as consultants to agencies of the government and serve as desired on committees of the Department of Defense or other national agencies as independent authorities."

TECHNICAL INFORMATION SERVICES "A comprehensive collection of classified and unclassified technical source material will be available as well as the services of professional librarians to make library searches.

"Other facilities include excellent laboratory equipment, access to computer and data processing services; private quarters will be provided as soon as the RESEARCH CENTER building is completed in the summer of '62."

MEN WITH SCIENTIFIC VISION... and a touch of the missionary spirit that plays a significant part in building a research capability of this order, are invited to inquire about key appointments now open in areas indicated at the right. (A doctoral degree, and at least eight years research experience, is mandatory).

Oceanography — to investigate natural phenomena, in order to arrive at a more perfect understanding of the effect of earth sciences on systems required by government. (A vessel will be provided)

Radiation Sciences — to increase understanding of plasmas, wave propagation; to fully explore energy conversion and infrared technologies.

Astrospace Environments — to study natural phenomena in order to provide a more perfect understanding of environmental boundaries of space systems.

Hydraulics & Pneumatics — to provide a fuller understanding of fluid technology in dynamic systems.

Guidance & Navigation — Terrestrial and Celestial — to develop a broader comprehension of the needs of future systems.

Physics — Specialist in Modern Materials research pertaining to solid state, fluid, magnetic and dielectric materials.

Chemistry — to develop and extend range and application of organic and inorganic materials. Activity will be in both materials and processes.

Metallurgy — to serve as authority on metallurgical properties of Modern Materials — function-wear, defect propagation and anelasticity.

Please write Dr. Langford at some length about your interests and past work. Copies of papers written or presented will be appreciated —and returned, if desired.

GP

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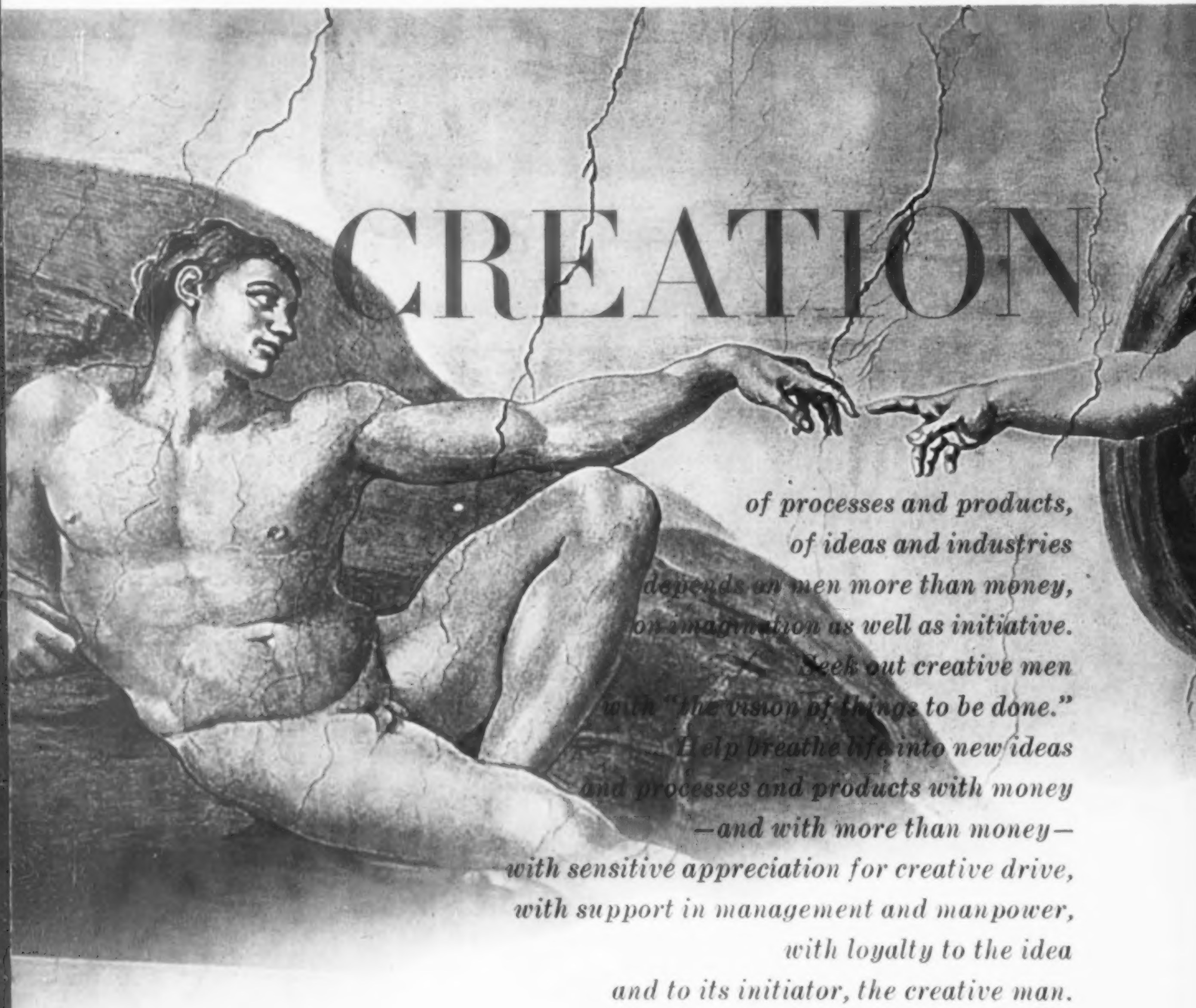

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